



**USACE JUNE 2014**

# Climate Change Adaptation Plan

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# EXECUTIVE SUMMARY

This US Army Corps of Engineers (USACE) June 2014 Adaptation Plan update, prepared at the direction of the USACE Committee on Climate Preparedness and Resilience (CCPR), describes our vision, goals, and strategic approaches, our progress on priority areas, and how we plan, integrate, and evaluate measures to adapt to climate change and increase our preparedness and resilience. The plan will be updated annually and will be publicly available to our staff, partners and stakeholders following the required review by the White House. USACE tracks climate preparedness and resilience through annual metrics that address external collaboration, improving knowledge about climate impacts and adaptation, progress assessing vulnerability, and development of policy and guidance.

This USACE Adaptation Plan describes activities underway to evaluate the most significant climate change related risks to, and vulnerabilities in, agency operations and missions in both the short and long term, and outlines actions that USACE is taking to manage these risks and vulnerabilities. This Plan contains a description of programs, policies, and plans USACE has already put in place, as well as additional actions that USACE will take to help us manage climate risks in the near term and build resilience in the short and long term. USACE is continuing to develop, implement, and update comprehensive plans that integrate consideration of climate change into agency operations and overall mission objectives.

USACE progress to date in supporting mainstreaming climate change adaptation has focused on clarifying our adaptation mission and goals and developing new policy and guidance to support adaptation implementation at multiple scales, from project-specific to nationwide. We

are applying our strategic approaches to the priority areas identified in previous years, with a heavy emphasis on external collaboration and pilot tests to help improve our knowledge so we can make progress on the policy and guidance needed to mainstream adaptation.

USACE will continue implementing our plan to improve climate preparedness and resilience and reduce vulnerabilities through adaptation to climate change. USACE vulnerability assessments support the identification and assessment of climate change related impacts on, and risks to, our ability to accomplish our missions, operations, and programs. We will continue to expand incorporation of climate uncertainty considerations into planning, design, construction, operation, and management of new and modified infrastructure and our military support missions. We expect our identified priority areas to evolve as we gain understanding and experience adapting to climate change, complete early elements, and confront and new challenges.

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# INTRODUCTION

USACE established an overarching *USACE Climate Change Adaptation Policy Statement* and a governance structure to support mainstreaming adaptation in 2011 following the release of Executive Order 13514 and its Implementing Instructions. With the release of the President's Climate Action Plan (PCAP) and Executive Order 13653, *Preparing the United States for the Impacts of Climate Change*, the policy has been updated as shown in the following section. Our policy requires USACE to mainstream climate change preparedness and resilience in all activities to help enhance the resilience of our built and natural water-resource infrastructure and the effectiveness of our military support mission, and to reduce potential vulnerabilities to the effects of climate change and variability. USACE is mainstreaming climate preparedness and resilience through four strategies: we focus on priority areas, we engage in external collaboration, we improve our understanding of climate change impacts and vulnerabilities, and we develop new policy and guidance to support adaptation implementation based on the best available and actionable science.

## What's new in the 2014 Adaptation Plan

The 2014 Adaptation Plan updates information in the 2013 Adaptation Plan and provides new information stemming from two significant Administration actions: the release of the PCAP in June 2013, and the Executive Order (EO) 13653, *Preparing the United States for the Impacts of Climate Change*, in November 2013. We've added several new sections here to reflect these actions, including a section on international leadership and collaboration and another on research and development (R&D) activities supporting climate change adaptation. The 2014 Adaptation Plan also meets requirements of the December 1, 2013, *Guidance on Preparing Federal Agency Climate Change Adaptation Plans* provided by Council on Environmental Quality (CEQ) in Accordance with Executive Order 13653.

## President's Climate Action Plan

The PCAP, released June 25, 2013, reinforces previous actions to conserve energy and reduce the greenhouse gas emissions that drive anthropogenic climate change (climate

change mitigation), acknowledges that we must prepare for adverse impacts of climate change (climate change adaptation), and stresses international leadership and collaboration for both mitigation and adaptation plans and actions.

The highest priority in the Climate Action Plan (CAP) is to prepare for the impacts of climate change by building stronger and more resilient communities and protecting natural resources based on sound science. Climate change is causing some aspects of weather to become more extreme, and this trend can be expected to continue into the future as climate continues to change. The economic and public health consequences of these climate-forced extremes require us to act now.

The three key pillars of the CAP are:

- Cut carbon pollution: Climate change mitigation to avoid unmanageable consequences

- Prepare for climate change: Climate change adaptation to manage unavoidable consequences
- Lead international efforts to combat climate change and prepare for its impacts

This Adaptation Plan primarily addresses adaptation in the context of the second two pillars, but also provides information on our efforts around biosequestration and integrating adaptation and mitigation.

### EO 13653, Preparing the United States for the Impacts of Climate Change

EO 13653, released on 1 November 2013, supplements *EO 13514 Federal Leadership in Environmental, Energy, and Economic Performance*, which is primarily concerned with water conservation and climate change mitigation through energy conservations and greenhouse gas emissions. Section 7(i) of EO 13514 required agencies to evaluate climate-change risks and vulnerabilities to manage the effects of climate change on the agency's operations and mission in both the short and long term. USACE completed several high-level analyses of vulnerabilities in accordance with Section 8(i), and began the process of phased vulnerability assessments which are being refined over time. Section 16 of EO 13514 laid out agency roles to support the Federal Adaptation Strategy, including participation in the Climate Change Adaptation Task Force (CCATF), development of a governance structure, and some general language about developing approaches, policies, and practices to support adaptation. The Assistant Secretary of the Army for Civil Works, Jo-Ellen Darcy, was named Senior Adaptation Point of Contact and served as the USACE principal on the CCATF. The USACE Climate Change Adaptation Steering Committee was formed to oversee USACE climate change adaptation activities. An overarching agency adaptation policy was signed by Jo-Ellen Darcy on June 3, 2011, and subsequent policy and guidance has been released through the Adaptation Steering Committee.

By contrast, EO 13653 contains very specific language, goals, and objectives to prepare the Nation for the impacts of climate change by undertaking actions to enhance climate preparedness and resilience. EO 13653 requires agency policy to engage in partnering and information sharing, support risk-informed decision-making and associated tools, incorporate adaptive learning so that experience informs and guides adjustments to future actions, and undertake climate preparedness planning. In doing so, agencies are to modernize federal programs to support climate resilient investment and manage lands and waters for climate preparedness and resilience. Specific requirements for agency Adaptation Plans are described. A new CCPR replaces the CCATF, and Council Working Groups are established, some of which continue CCATF Working Groups. A State, Local, and Tribal Leaders Task Force was



### USACE Roots in Climate Change: Deep Ice Cores

The US Army Snow, Ice and Permafrost Research Establishment (SIPRE), the precursor to the ERDC Cold Regions Research and Engineering Laboratory (CRREL), led the effort to develop a deep ice core drilling program in the US for the International Geophysical Year (IGY), lasting 18-months from June 1957–December 1958. The IGY was a major international scientific endeavor involving 68 countries. Dr. Henri Bader, SIPRE's chief scientist, a renowned ice and snow physicist who had pioneered shallow ice core drilling efforts in Alaskan glaciers, led the effort to develop a deep coring program. During IGY and testing periods conducted in Greenland leading up to IGY, SIPRE successfully recovered and analyzed the first deep cores in northwest Greenland in 1956 (to 305m) and in 1957 (to 411m), and in Antarctica at Byrd Station in 1957–1958 (to 307m) and at Little America V in 1958–1959 (to 264m through the Ross Ice Shelf). Following the IGY effort to develop deep ice core drilling technology, SIPRE/CRREL staff began efforts to drill through the polar ice sheets to the bedrock underlying the ice, first at Camp Century, Greenland in 1966 (1390m deep) and then at Byrd Station in Antarctica in 1968.

SIPRE/CRREL staff worked in collaboration with several national and international research partners, most notable Willi Dansgaard of the University of Copenhagen and Hans Oeschger of the University of Bern, to develop cutting edge research and analysis techniques to examine the cores that had been shipped back to the laboratory. The three collaborated to develop some of the first techniques to reveal the past climate history from ice cores; notably the recovery of past atmospheric compositions from air trapped in the ice cores at depth and the subsequent discovery of glacier-interglacial cycling of CO<sub>2</sub> in the atmosphere.

Starting in the 1970's, CRREL began development of the Greenland Ice Sheet Program (GISP) with the ambitious goal of drilling through the Greenland Ice Sheet to bedrock from the ice sheet summit. GISP represented a major international effort, with Langway (CRREL), Dansgaard and Oeschger leading the project. The program successfully drilled to bedrock in 1993 at a site now known as GISP2 (3053m deep), now the location of the US Summit Station, and also by the Danish-led European group at GRIP (3029m deep), 30km to the east of GISP2. These two cores represented the oldest climate data determined from ice cores at the time, dating back to 140kyr before present. The scientific results of the first deep ice cores have yielded unique windows to past events on Earth and provided the foundation by which many nations have since drilled deep ice cores in both polar regions.

Reference Langway, *The History of Early Polar Ice Cores*, ERDC/CRREL TR-08-1, 2008.

convened to make recommendations to improve climate preparedness and resilience for states, local communities, and tribes.

## 2013-2014 Highlights

An example of progress built on USACE strategies is the interagency *Sea Level Rise Tool for Sandy Recovery*, now being used in New York and New Jersey, where planning and rebuilding is underway. The team included multi-disciplinary representatives from USACE, the National Oceanic and Atmospheric Administration, the Department of Homeland Security's Federal Emergency Management Agency, and the U.S. Global Change Research Program. The Sea Level Rise Tool incorporates the *USACE sea-level rise calculator* previously developed to support USACE adaptation planning and implementation. The interagency tool won a *2013 GreenGov Presidential Climate Champion Award*. Other successes are detailed in this June 2014 updated Adaptation Plan.



**Figure 1.** Image of the GreenGov Presidential Awards. The team was recognized for developing the Sea Level Rise Tool for Sandy Recovery which is now being used in New York and New Jersey where planning and rebuilding is underway.

One outcome of our strategic approach is our first technical guidance for adaptation, *Procedures to Evaluate Sea-Level Change Impacts, Responses, and Adaptation*, which completed a wide internal and external review in 2013 and was signed in 2014. This adaptation implementation guidance was drafted by an extensive interagency, international and multi-disciplinary team, incorporating team members from USACE, partner agencies, and other experts in academia and the private sector.

Our collaborative approach is demonstrated by the study conducted by General Accountability Office (GAO) between October 2012 and November 2013. The GAO released 14-23, *Federal Efforts Under Way to Assess Water Infrastructure Vulnerabilities and Address Adaptation Challenges*, in December 2013. The findings conclude “The Corps and Reclamation have collaborated together and with others in a manner that is generally consistent with practices that GAO has identified as important to enhancing and sustaining collaboration among agencies. The Corps and Reclamation have made collaboration a key element of their policy and plans for adapting to the effects of climate change and have reinforced accountability for collaboration through agency performance management systems.” No changes were recommended by GAO as a result of this study.



# ADAPTATION POLICY STATEMENT

The primary and overarching policy document for USACE is the *USACE Climate Preparedness and Resilience Policy Statement*, signed by Assistant Secretary of the Army Jo-Ellen Darcy in June 2014.

As the Nation's largest and oldest manager of water resources, the US Army Corps of Engineers (USACE) has long been successfully adapting its policies, programs, projects, planning, and operations to impacts from important drivers of global change and variability.

It is the policy of USACE to integrate climate change preparedness and resilience planning and actions in all activities for the purpose of enhancing the resilience of our built and natural water-resource infrastructure and the effectiveness of our military support mission, and to reduce the potential vulnerabilities of that infrastructure and those missions to the effects of climate change and variability. USACE shall continue undertaking its climate change preparedness and resilience planning, in consultation with internal and external experts and with our districts, divisions, and Centers, and shall implement the results of that planning using the best available – and actionable – climate science and climate change information. USACE shall also continue its efforts with other agencies to develop the science and engineering research on climate change information into the actionable basis for adapting to climate change impacts. Furthermore, USACE shall continue to consider potential climate change impacts when undertaking long-term planning, setting priorities, and making decisions affecting its resources, programs, policies, and operations.

These actions, which USACE is now conducting and has outlined for the future, are fully compatible with the guiding principles and framework of the Council on Climate Preparedness and Resilience and its predecessor, the Federal Interagency Climate Change Adaptation Task Force; with Executive Order 13653 and its December

19, 2013 instructions *Preparing Federal Agency Climate Change Adaptation Plans In Accordance with Executive Order 13653*; and with Executive Order 13514 and the *Implementing Instructions for Federal Agency Climate Change Adaptation* issued on March 4, 2011.

USACE understands and is acting to integrate climate adaptation (managing the unavoidable impacts) with mitigation (avoiding the unmanageable impacts). USACE recognizes the very significant differences between climate change adaptation and climate change mitigation in terms of physical complexity, fiscal and material resources, level of knowledge and technical readiness, and temporal and geographic scale. These differences mean that very different knowledge, skills, and abilities are needed to understand, plan and implement climate preparedness and resilience policies and measures as compared to the ones for implementing mitigation measures. It is the policy of USACE that mitigation and adaptation investments and responses to climate change shall be considered together to avoid situations where near-term mitigation measures might be implemented that would be overcome by longer-term climate impacts requiring adaptation, or where a short-term mitigation action would preclude a longer-term adaptation action.

Work to understand and adapt to the impacts of climate and global change is well underway at USACE, and the policy enunciated here is closely aligned with the USACE Campaign Plan and the USACE Civil Works Strategic Plan. USACE has several integrated programs directed at parts of climate change adaptation; in addition, many coordinated elements from other programs support the development of approaches to understand and mainstream climate change

adaptation. Mainstreaming climate change adaptation means that it will be considered at every step in the project life cycle for all USACE projects, both existing and planned, through a logical, rational, legally justifiable process that develops practical, nationally consistent, and cost-effective adaptation measures, both structural and nonstructural, to reduce vulnerabilities and enhance the resilience of our water-resource infrastructure.

The magnitude and complexity of climate change impacts facing water-resource managers in the US has spurred USACE to embark on closer, more fruitful interagency cooperation for developing methods supporting climate change adaptation. Close collaboration, both nationally and internationally, is the most effective way to develop the measures to identify and reduce the USACE mission vulnerabilities to potential future climate changes. USACE has demonstrated its commitment to engage and lead such collaboration through efforts including the “Building Strong Collaborative Relationships for a Sustainable Water Resources Future Initiative” and the federal interagency Climate Change and Water Working Group (CCAWWG).

It is the policy of USACE that these and other productive collaborative efforts around climate and global change adaptation shall continue.

This policy establishes the Assistant Secretary of the Army for Civil Works as the Agency official responsible for ensuring implementation of all aspects of this policy. This policy does not alter or affect any existing duty or authority and recognizes that USACE has established the USACE Committee on Climate Preparedness and Resilience to oversee and coordinate agency-wide climate change adaptation planning and implementation. The Committee is chaired by the USACE Chief, Engineering and Construction, and reports regularly to the Assistant Secretary of the Army for Civil Works.

This policy statement reaffirms and supersedes the commitment made by USACE in its June 3, 2011 Climate Change Adaptation Policy Statement. This policy shall be effective beginning June 27, 2014, for all USACE missions, operations, programs and projects and shall remain in effect until it is amended, superseded, or revoked.

Signed,



**Jo-Ellen Darcy**

Assistant Secretary of the Army for Civil Works




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“Adaptation is not optional.”

Mr. James C. Dalton, PE, SES, Chair of the USACE  
Climate Change Adaptation Steering Committee, January 19, 2012

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# MAINSTREAM ADAPTATION

Effective climate change preparedness and resilience is especially important for USACE because the hydrologic processes underlying water resources management are very sensitive to changes in climate and weather, and because those same changes affect our military support missions, both nationally and internationally. Our Civil Works Program and associated water resources infrastructure represent a tremendous federal investment supporting public safety and local and national economic growth. Our Military Missions work provides engineering, construction, real estate, stability operations, and environmental management products and services for the Army, Air Force, other assigned U.S. Government agencies and foreign governments. Both Civil and Military missions support national security. For all these reasons, USACE has a compelling need to understand and prepare for climate change and variability.



The USACE Climate Change Preparedness and Resilience Policy Statement requires USACE to mainstream climate change adaptation in all activities to help enhance the resilience of our built and natural water-resource infrastructure and military missions reduce their potential vulnerabilities to the effects of climate change and variability. Mainstreaming means to integrate and incorporate climate change and variability considerations for missions and operations in all phases of the project lifecycle for both new and existing projects. The policy statement also requires USACE begin adaption now based on the best available and actionable science to consider the impacts of climate change when planning for the future. Our goal is to successfully perform our missions, operations, programs, and projects despite the challenges of global and climate change.



# GOVERNANCE FRAMEWORK

The Assistant Secretary of the Army for Civil Works is the designated USACE Senior Adaptation Point of Contact responsible for ensuring implementation of the USACE Climate Change Adaptation Policy Statement issued June 3, 2011 and updated in this Plan.

The 2011 policy Statement also established the USACE Climate Change Adaptation Steering Committee (ASC), chaired by the USACE Chief, Engineering and Construction, to oversee and coordinate agency-wide climate change adaptation planning and implementation. In 2014, the ASC was renamed the USACE CCPR to more clearly reflect the intent of EO 13653 and the PCAP. The CCPR acts as the highest level of authority for climate preparedness and resilience, in USACE. The CCPR establishes strategic

direction; reviews/monitors existing adaptation programs, activities and policy implementation; makes the strategic decisions related to implementing adaptation across USACE; and coordinates the integration of adaptation and mitigation activities with the USACE Strategic Sustainability Committee.

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“During the past few months, I’ve had many opportunities to engage with groups and talk about the role of the Corps of Engineers in providing vital water resources infrastructure to the Nation. Without fail, I am always asked a question about how we are dealing with climate change. I am very proud that USACE is on the leading edge of important research and projects that will help ensure our infrastructure and operations are prepared for future conditions. Climate Change and Climate Adaptation issues are shared responsibilities... it’s going to take a team of teams throughout the government and private sector.”

-Thomas P. Bostick, Lieutenant General, US Army, Commanding General and Chief of Engineers, USACE Adaptation Newsletter December 2013

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# CLIMATE CHANGE ADAPTATION PLAN

The USACE 2014 Climate Change Adaptation Plan represents an update of the 2013 USACE Climate Change Adaptation Plan submitted to CEQ and Office of Management and Budget (OMB). The plan also addresses additional topics introduced in the PCAP and EO 13653. Our plan supports our objective to mainstream climate change adaptation in all activities to help enhance the resilience of our built and natural water-resource infrastructure and military support missions reduce potential vulnerabilities to the effects of climate change and variability.

## Strategy

Goals and elements of the Adaptation Plan are incorporated in both the USACE Campaign Plan and the Army Campaign Plan. Based on our high-level assessments of vulnerability to climate change, the USACE Adaptation Plan employs four primary strategies to achieve our objective:

- Focus on priority areas
- Engage in meaningful external collaboration
- Improve USACE knowledge for water resources management and infrastructure resilience
- Develop policy and guidance for infrastructure resilience

Each of these strategies is described in detail below, together with a description of current status. The USACE military support activities will be guided by the Department of Defense (DoD) Adaptation Plan and specific Department plans, policies, and guidance.

The USACE Climate Adaptation Plan is implemented primarily through two programs at USACE: the Interagency Performance Evaluation Task Force (IPET)/Hurricane Protection Decision Chronology (HPDC) Lessons Learned Implementation Team and the Responses to Climate

Change program (RCC). These programs are charged with developing the methods, tools, and guidance to improve the resilience of our built and natural infrastructure and military support missions through a collaborative, proactive, nationally consistent, and regionally sensitive framework and program of actions. These actions include improving our understanding of climate impacts to missions and operations, assessing vulnerabilities, and identifying specific actions to minimize risk and capitalize on opportunities to improve infrastructure resilience.

## Focus on Priority Areas

Climate change poses numerous challenges to USACE missions and operations. Based on the best available and actionable science, our high-level vulnerability analyses, and USGS Circular 1331 (2007), we identified six adaptation priority areas as requested in the February 29, 2011 *Statement on Preparing Adaptation Plans*, in the 2011 USACE Adaptation Plan and Report. Focusing our energy on priority areas helps us to make progress faster and more effectively. In 2013, we added a new area to address more explicitly the fundamental reason for mainstreaming adaptation: infrastructure resilience. In 2014 we have moved discussions on the Administration's cross cutting strategies to Appendix D to reflect progress made in previous years and the mainstreaming of these strategies. The priority areas

below represent core issues supporting our fundamental need to improve infrastructure resilience in changing conditions:

- Infrastructure Resilience
- Vulnerability Assessments
- Risk-Informed Decision-Making for Climate Change
- Nonstationarity
- Portfolio of Approaches
- Metrics and Endpoints

Our progress on these priorities benefits from external collaboration and an active program to improve our knowledge about climate change and adaptation so we can develop policies and guidance to support adaptation planning and implementation. Additional priorities will be identified in the future as we gain understanding and experience by adapting to climate change.

### Infrastructure Resilience

(USACE) Civil Works Program and its water resources infrastructure – built and natural, structural and nonstructural – represents a tremendous federal investment that supports public health and safety, regional and national economic development, and national ecosystem restoration goals. The hydrologic and coastal processes underlying this water resources management infrastructure are very sensitive to changes in climate and weather. Therefore, USACE has been working for several years now to understand and adapt to the effects of climate change and variability to continue providing authorized performance despite changing, to help enhance the resilience of our built and natural water-resource infrastructure and reduce its potential vulnerabilities to the effects of climate change and variability. The activities undertaken to improve infrastructure resilience related to climate change support other important USACE infrastructure programs and help to inform and improve our Military Missions and Civil Works portfolio of work.

During 2013, USACE made progress on developing approaches, policy, guidance and tools to support infrastructure resilience. In September 2013, USACE published *Coastal Risk Reduction and Resilience: Using the Full Array of Measures*, which addresses our capabilities to help reduce coastal risks from and improve resilience to extreme events and increasing extreme water levels. The approach uses an integrated planning approach that draws from the full array of coastal risk reduction measures. These measures include natural or nature-based features (e.g.,



### North Atlantic Coast Comprehensive Study

The North Atlantic Coast Comprehensive Study (NACCS) is a collaborative effort, bringing together governmental, academic, and non-governmental experts in coastal planning, engineering and science to collaboratively develop a risk reduction framework for the 31,000 miles of coastline within the North Atlantic division that were

affected by Hurricane Sandy. The study is authorized up to \$20 million (\$19 million after sequestration) and will be submitted to Congress in January 2015. For more information, please visit <http://www.nad.usace.army.mil/CompStudy>.

The Congressional response to the devastation in the wake of Hurricane Sandy represents a need to address as a regional system the vulnerability of populations at risk in coastal regions in the U.S. Army Corps of Engineers (USACE) North Atlantic division. The NACCS comprehensively evaluates existing and planned measures to reduce the flooding risk from tidally influenced storm surges as well as other alternatives for areas at risk to future storm damages.

The goals of the Comprehensive Study are to (1) provide risk reduction strategies to subjected vulnerable coastal populations, and (2) support coastal resilient communities and sustainable coastal landscape systems, considering future sea level rise and climate change scenarios, to reduce risk to vulnerable population, property, ecosystems, and infrastructure. The Comprehensive Study includes a coastal framework as well as storm suite modeling, coastal GIS analysis, and related evaluations for the affected coastlines. The study identifies existing natural and nature-based infrastructure, includes an evaluation of the performance of natural and nature-based infrastructure during Hurricane Sandy and other recent storms, and considers the performance of natural and nature-based infrastructure in reducing the impacts of coastal storm flooding, as well as other impacts at a larger scale and as a system.

The Comprehensive Study team is led by the USACE Coastal Storm Damage Reduction Planning Center of Expertise and includes planners and engineers from North Atlantic division districts and other districts, the USACE Engineer Research and Development Center, and the USACE Institute for Water Resources, incorporating other USACE resources and expertise as appropriate.

wetlands and dunes), nonstructural interventions (e.g., policies, building codes and emergency response such as early warning and evacuation plans), and structural interventions (e.g., seawalls and breakwaters).

In 2013 and 2014, USACE has addressed infrastructure resilience in a particular place explicitly through the North Atlantic Coast Comprehensive Study (NACCS, see inset box). The NACCS approach is informed by the *Infrastructure Systems Rebuilding Principles* developed jointly by USACE and the National Oceanic and Atmospheric Administration (NOAA) in 2013. These principals anticipate a changing environment, integrate economic, social, and environmental

resiliency and sustainability and promote long term community protection on a regional scale.

In December 2013, we issued Engineering and Construction Bulletin (ECB) 2013-33, *Application of Flood Risk Reduction Standard for Sandy Rebuilding Projects*. The ECB provides information on how to apply the April 2013 Flood Risk Reduction Standard (FRRS) for Sandy Rebuilding Projects issued by Housing and Urban Development Secretary Donovan. The ECB outlines a procedure to establish applicability, determine best available base flood elevation (BFE), and calculate the minimum flood risk reduction elevation required. An accompanying [web tool](#) was also provided.

USACE is actively participating in development of the proposed Federal Flood Risk Reduction Standard identified in the PCAP (p. 15, "Preparing for Future Floods"). This activity is being undertaken by the Mitigation Framework Leadership Group (MitFLG). USACE has been actively involved with all three interagency teams developing the standard: Policy, Stakeholders, and Science.



### Vulnerability Assessments

Climate vulnerability assessments are necessary to help guide adaptation planning and implementation so that USACE can successfully perform its missions, operations, programs, and projects in an increasingly dynamic physical, socioeconomic, and political environment. Several activities that USACE has completed in connection with high level assessments of vulnerability to climate change in its Civil Works program support our continued vulnerability assessments. Those outcomes include a preliminary assessment presented in USGS Circular 1331 (2007) and a high-level analysis of the vulnerability of USACE missions and operations to climate change submitted to CEQ summarized in Appendix B here.

USACE is currently conducting two nationwide screening-level assessments of the vulnerability of USACE Civil Works mission, operations, programs, and projects to climate change.



These screening-level vulnerability assessments are designed to be conducted in phases (so the initial assessment can be refined) using a modular approach (so new and updated information can replace initial information) and supported by district-acceptable tools and visualizations. The analyses build on existing, national-level tools and data, including specific indicators of vulnerability representing USACE business lines.



Figure 2. View of progress on IVA as of June 16, 2014.

In 2013, USACE began a screening-level initial vulnerability assessment (IVA) of projects with respect to sea level change. A web-based tool based on USACE geospatial databases and our sea level rise calculator. Teams from the USACE districts with coastal projects are performing the IVA, which will serve as the basis for more detailed vulnerability assessments in the future.

As of mid-June 2014, about 80% of over 1600 coastal projects had been assessed (Figure 2), with assessments in three of seven divisions 100% complete (Pacific Ocean division, Southwest division, and South Pacific division). The remainder of the divisions range from 66% to 96% complete.

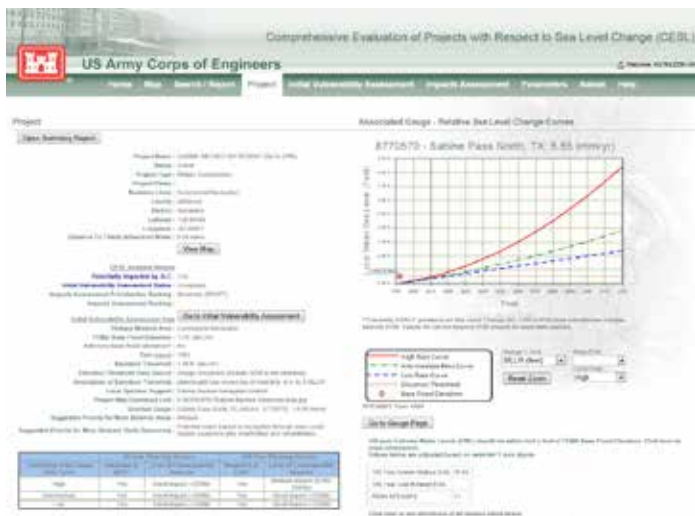
These assessments have identified over 400 projects potentially impacted by sea level change to date and just as importantly, identified more than 875 projects that

appear to be robust to future changes described with this assessment tool. Figure 3 presents an example of a project assessment, which include a graph showing the USACE sea level scenarios plus a trigger elevation threshold determined by district staff after considering the project purposes and potential impacts to project performance. In 2013, USACE also developed the tools for the next step in the assessment, and began a pilot study to help develop methods for more detailed assessments of vulnerable projects at one of our hurricane barriers.

For inland hydrology, in 2012, we completed a proof-of-concept study focused primarily on the potential exposure to climate change-induced changes in freshwater run off at the level of HUC-4 watersheds in the contiguous U.S. (CONUS). This assessment supports exploration of the vulnerability of USACE Civil Works business lines (see Appendix B) and also an aggregated assessment across all business lines. In 2013, we updated this web-accessible, geospatially realized, indicator-based tool to include updated hydrology derived from the model outputs calculated for the World Meteorological Organization Coupled Model Intercomparison

Project, Phase 5 (CMIP5). (See discussion in the section below on “Coupling Science and Engineering.”)

Visualization techniques were developed to support understanding and knowledge transfer (Figure 4). As of June 2014, the watershed assessment has identified the 20% most vulnerable watersheds for each business line (flood risk reduction, navigation, ecosystem restoration, hydropower, recreation, regulatory, water supply, and emergency management) based on the indicators and assumptions used. Aggregating across business lines allows us to see which watersheds are among the 20% most vulnerable to multiple business lines, an important consideration for impacts to multipurpose projects. This information can be used to support streamlined project planning in accordance with USACE Planning Modernization. Data developed for this assessment is currently being considered for application in support of Army adaptation planning. The Office of the Assistant Secretary of the Army, Installations, Energy, and Environment, tasked the USACE Engineer Research and Development Center to develop an adaptation planning framework consistent, beginning with phased assessments of vulnerability to climate change.



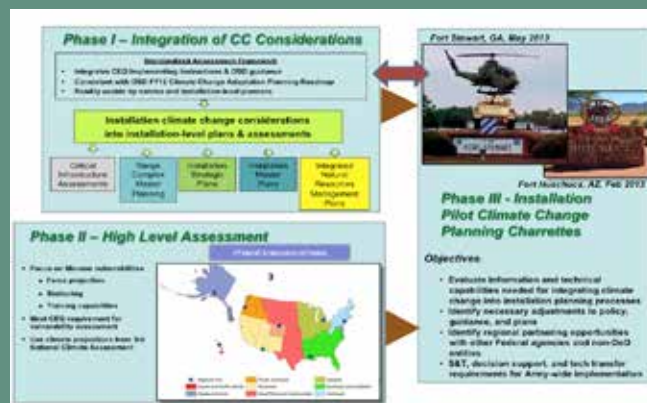
**Figure 3.** Example of output from USACE nationwide screening assessment of vulnerability to coastal climate change at the project level. Data is entered by USACE district staff into a web tool tied to USACE geospatial databases and NOAA tide gauge information. The tool considers a 100-year planning horizon and allows for estimates of impacts due to sea level change and extreme water levels.



**Figure 4.** Example visualization of USACE nationwide screening assessment of vulnerability to climate change at the HUC-4 level. Top depiction shows the top 20% most vulnerable HUC-4 watersheds for the far future (30 year period 2070-2100) for the Water Supply business line in a wetter future. Bottom left aggregates vulnerability across all business lines. Bottom right shows contribution of indicators to vulnerability for the selected watersheds

## Support to Army for Implementing Climate Considerations in Established Army Installation Planning Processes

The Office of the Assistant Secretary of the Army, Installations, Energy, and Environment, tasked the USACE Engineer Research and Development Center to develop an adaptation planning framework consistent with CEQ and the goals of the DoD Climate Change Adaptation Roadmap to integrate climate change planning in existing Army planning processes. This effort outlines requirements to incorporate climate change considerations in five major Army installation planning processes: Installation Strategic Plan, Master Plan, Range Complex Master Plan, Integrated Natural Resource Management Plan, and Critical Infrastructure Risk Management. Relationships among current plans and supporting policy and implementation guidance are assessed with recommendations for modifications and additions that would support integration of climate change considerations in installation planning. For FY14, this effort will extend the Army Climate Change Planning Framework to include emergency response plans and potable water master plans. In addition, scoping of technical services (data sources, decision support, and analytical tools) to support the Army adaptation planning framework at the installation level will be developed.



Several climate-change adaptation pilot projects at USACE have addressed the framework. The Hamilton Wetland Restoration Project (HWRP) tested the proposed risk framework and evaluated its application to the USACE planning phase. The West Maui Watershed Study tested the framework to collaboratively identify climate risks and to develop adaptation strategies. The Lower Columbia River Estuary pilot study is applying the framework to ecosystem restoration. The risk framework is now under revision based on preliminary results from pilot studies and an internal review. The risk management framework will be a foundation for developing strategies to incorporate climate change into the decision making processes of USACE.



## Nonstationarity

Stationarity, or the assumption that the statistical characteristics of hydrologic time series data are constant through time, enables the use of well-accepted, simplified statistical methods in water resources planning and design. Climate change has shown this assumption to be invalid (Milly et al. 2008).

Planning for continued and resilient performance under future water resources conditions is fundamental to our missions and operations, so developing methods and procedures to address climate change-forced nonstationarity is a high priority action for USACE. Considerable progress has been made in this area, as highlighted in the inset box on the following page. Since our 2010 international and interagency workshop on nonstationarity, followed by a proceedings and a special collection of journal papers, USACE has made progress in the critical area of nonstationary hydrology. USACE works with interagency collaborators (USGS, the Department of Homeland Security (DHS) Federal Emergency Management Agency (FEMA), Department of Interior (DOI) Bureau of Reclamation (Reclamation), and the Department of Transportation (DOT) Federal Highways Administration (FHWA)) as well as academic experts. The team also includes interagency collaboration with the agencies that work under the Advisory Committee for Water Information Subcommittee for Hydrology.

## Risk-Informed Decision-Making for Climate Change

Risk-informed decision making is a crucial component of USACE adaptation to climate change. Since climate change will require making sequential decisions over time and updating design and plans to incorporate new and changing information we have been testing a draft framework that addresses the entire project life cycle. Risk assessment includes both consequence and likelihood assessment, and the draft framework recognizes the potential challenges of assigning probabilities to uncertain future conditions. Formulation of risk management alternatives under changing conditions is a crucial component of the approach. The framework emphasizes the need for stakeholder involvement throughout the decision process.

## Translating Science for Decision-Making: Nonstationarity

Our approach to obtain external peer review for critical aspects on nonstationarity that will support policy and guidance. Several journal papers by team members have been peer-reviewed and published in 2013 and early 2014:

- Villarini et al. (2013) looks at what the general circulation models underlying the IPCC 5th Assessment Report indicate about precipitation events with annual exceedance probabilities of 0.1 and 0.01, concluding that projections indicate that the more remote probability (0.01) events may be changing more than the less remote probability (0.1) events. This is very important for flood-related planning and engineering design.
- Vogel et al. (2013) explores how societies may respond to global change, in keeping with the USACE role as a provider of public water resources infrastructure.
- Lavers and Villarini (2013a), addresses the role of atmospheric rivers (AR) in flooding in the Central US. The work lays a foundation for future work to assess future projected changes to ARs to determine future risks from flooding over this area.
- Lavers and Villarini (2013b) considers the ability of numerical weather prediction (NWP) models to predict an extreme hydrological event. NWPs integrate current weather conditions through mathematical models of the atmosphere-ocean system to forecast future weather. The study looked at forecast skill over varying spatial areas, concluding that forecast skill is improved in larger spatially-averaged areas, especially in complex topography.
- Two papers examined climate impacts in the South Atlantic region: Patterson et al. (2013a) studied drought characteristics to understand whether drought has become more severe in this region over time. This paper noted that while drought characteristics did not change significantly in the 20th century (Patterson et al. 2012), the combination of decreasing average streamflow and increasing water use have produced significant stress on existing water infrastructure. Patterson et al. (2013b) considered the effects of climate and other human-induced impacts affected streamflow in the same region.



## Portfolio of Approaches

The wide portfolio of possible approaches for producing and using climate science and climate change information for water resource adaptation questions can bewilder planners and engineers because each method or analytical technique in this portfolio brings uncertainties and particular deficiencies, some of which are large or only partly characterized and poorly quantified. In 2012, USACE, together with Reclamation, the National Center for Atmospheric Research (NCAR), and academic experts, began a joint project to answer two questions of particular importance in making decisions about which methods are more or less appropriate for use in a particular decision environment. These are: how are the portrayals of weather impacts under climate change sensitive to downscaling method? And, how are the portrayals of hydrologic impacts sensitive to hydrologic evaluation method? The work should help operating and resource management agencies looking to use these techniques to inform their climate adaptation planning currently lacking good practice guidelines for helping them assess the approaches and choose appropriate ones for particular adaptation decisions.

“Managing water resources as a collaborative endeavor is becoming increasingly crucial as society faces demographic, economic, institutional, and climate changes manifesting across the U.S. and around the globe. These changes portend a different understanding of the risks associated with the occurrence, location, intensity and impacts of extreme events—including floods and droughts...”

- Mr. Steven L. Stockton, Director of Civil Works, U.S. Army Corps of Engineers, in “Responding to National Water Resources Challenges”

The Reclamation, the USACE and other water management agencies require reliable, science-based methods for incorporating climate change information into longer-term water resources planning. Such planning assessments must quantify projections of future climate and hydrology. The common practice is to begin by developing relationships between current observed climate and climate projections over the assessment region. Because of the spatial resolution and biases of climate projections from global climate models were not designed for local to regional hydrologic assessments, this step relies on some form of spatial downscaling and bias correction, which produces watershed scale weather information to drive simulations of hydrology and other water resource management conditions (e.g., water demands, water quality, environmental habitat).

Water agencies continue to face decisions about the choice of downscaling method(s), the selection and configuration of hydrological models, and of observational datasets. There is a critical need to understand the ramification of these methodological decisions, as they affect the signal and uncertainties produced by climate change assessments, and thus the effectiveness of these results to support adaptation planning and decision-making.

The overarching goal of the project is to identify strengths and weaknesses of current techniques used for downscaling climate projections and assessing hydrologic conditions toward better guidance on adaptation planning. Results from this evaluation steer research and development investments to develop improved methodologies.

Reclamation and USACE, in collaboration with the NOAA National Weather Service recently assessed the use of weather and hydrologic forecasts for short-term water management. The resulting report *Short-Term Water Management Decisions: User Needs for Improved Weather and Climate Prediction Information* identified gaps related to better use of weather, climate, and hydrologic information (i.e. monitoring and forecasts) in short-term water management decisions. Short-term decisions in this case are those associated with look-ahead periods of generally one year or less. Among other elements, the ST Doc described how different weather and hydrologic information products are used to support different water management decisions.

As a first step toward addressing the identified needs, NCAR is undertaking a comprehensive predictability assessment to quantify and document the major sources of skill and uncertainties in hydrologic monitoring and prediction products, and to investigate the potential for current state of the art datasets and techniques to reduce these uncertainties. In particular, the project will quantify the impact of different sources of uncertainty on different

types of forecasts (e.g., 1-day stage forecasts, 3 month volume forecasts), at different forecast initialization times throughout the year (e.g., forecasts initialized on October 1st versus April 1st), and in different hydroclimate regions (e.g., regions with/without substantial snow storage; regions with varying degrees of climate predictability). Integrating the Reclamation USACE assessment of user needs with an assessment of the opportunities to improve hydrologic prediction products will provide a foundation for identifying future research and development priorities.

The overarching goal of this project is to identifying and prioritize the research necessary to improve hydrologic monitoring and prediction products in response to user needs.



### Metrics and Endpoints

Appropriate frameworks and metrics for assessing the efficiency and effectiveness of climate change adaptation activities are crucial. These are needed for achieving our combined objectives of developing practical, nationally consistent, legally justifiable, and cost effective climate change actions, both structural and nonstructural, and for reducing the vulnerabilities and improving the resilience of water-resource infrastructures at risk from climate change threats. USACE has instituted and is reporting annually on metrics and endpoints in the USACE Campaign Plan (Action 2c.4 Improve CW Portfolio Performance in Changing Climatic Conditions) and the Army Campaign Plan. These are high-level guiding documents that govern strategic direction and implementation actions for USACE within Army and for Army within DoD.

The three major objectives in the Army Campaign Plan are #8-3.5 (Develop nationally consistent approach to climate change adaptation through collaboration with aligned agencies), 8-3.6 (Produce assessments of climate change vulnerabilities that inform adaptation planning for the CW portfolio), and 8-3.7 (Develop policy and guidance supporting improved CW portfolio performance in changing climatic conditions). USACE has consistently met nearly all its climate change metrics in 2013 and intends to continue doing so in 2014.

### ***Integrated Water Resources Management is characterized by:***

- **Sustainable outcomes**—the practice of making decisions and taking coordinated actions for outcomes and benefits that use or affect current economic, environmental and quality of life resources conditions in ways that preserve these resources for future generations.
- **Collaborative planning**—a process that avails collaboration to secure the input of all stakeholders about their interests and needs.
- **A systems perspective**—a systems approach that arrays interests and needs as input variables, modeling a system of interdependent variables with multiple outputs.
- **A geographic context**—a geographic perspective that examines who is doing what where at a broad geographic scale, e.g., a river basin, watershed or coastal zone.
- **Balanced aims**—a process that seeks to balance multiple objectives as diverse desired outputs producing multiple benefits.

### **Engage in Meaningful External, Collaboration**

USACE understands that close collaboration, both nationally and internationally, is the most effective way to develop practical, nationally consistent, and cost-effective measures to reduce potential vulnerabilities resulting from global changes (Stockton and White 2011). That is why we work closely with other agencies having aligned mission areas as we work to understand climate change impacts and to develop measures to adapt to these impacts. Our appreciation for the benefits of collaboration is also why we have provided support in the form of our senior engineers and scientists to the federal Interagency Climate Change Adaptation Task Force (ICCATF) working groups, now operating as CCPR Working Groups, to the Federal Adaptation Community of Practice, the National Climate Assessment, and to US Global Change Research Program, among others.

### **Interagency Climate Change Adaptation Task Force**

USACE played an active role in the ICCATF between its inception in spring 2009 and its replacement by the CCPR (see below). The Assistant Secretary of the Army for Civil Works was the USACE representative to the ICCATF, which was composed of more than 20 federal agencies and Executive branch offices co-chaired by CEQ, NOAA, and the OSTP. The ICCATF formed a number of working groups to help develop recommendations to support agency climate change adaptation planning and implementation. USACE actively participated in many of these, including the Agency Adaptation Processes working group (which developed recommendations for the Implementing Instructions (CEQ and OMB 2011)),

### **Interagency Sea Level Rise Tool for Sandy Recovery**



More than 8 million people live in areas at risk of coastal flooding. Along the U.S. Atlantic Coast alone, almost 60 percent of the land that is within a meter of sea level is planned for further development, with inadequate information on the

potential rates and amount of sea level rise. Global sea level rise has been a persistent trend for decades. It is expected to continue beyond the end of this century, which will cause significant impacts in the United States. Scientists have very high confidence (greater than 90% chance) that global mean sea level will rise at least 8 inches (0.2 meter) and no more than 6.6 feet (2.0 meters) by 2100. Many of the nation's assets related to military readiness, energy, commerce, and ecosystems that support resource-dependent economies are already located at or near the ocean, thus exposing them to risks associated with sea level rise.

Hurricane Sandy was a vivid reminder that coastal communities are vulnerable to damage from storms and flooding. Post-Sandy recovery provided an opportunity to reduce vulnerability and increase resilience further into the future by incorporating sea level rise information into decisions about how and where to rebuild, or to start new development. The Hurricane Sandy Rebuilding Task Force requested that the US Global Research Program, together with FEMA, NOAA, and USACE, develop an interagency tool to assist those in the Sandy recovery area to take future risks into account using the best available science and data. The Sandy Sea Level Rise Tool, released in July 2013, has three major components:

- Best available flood mapping by FEMA,
- Potential future water elevation calculated by the USACE sea level change calculator based on sea level rise scenarios defined by NOAA and the New York City Panel on Climate Change, and
- NOAA maps showing how sea level rise could impact future flood areas

The Sandy Sea Level Rise Tool development team was recognized as a Climate Champion, receiving a 2013 GreenGov Presidential Award.

### **Council on Climate Preparedness and Resilience**

The CCPR (Council) was established by Executive Order 13653 in November 2013. The Council, co-chaired by the Chair of the CEQ, the Director of OSTP, and the Assistant to the President for Homeland Security and Counterterrorism, includes senior officials from 30 agencies and departments (see Appendix D). The Council replaces the ICCATF, which was established under EO 13514. The Assistance Secretary of the Army for Civil Works represents USACE on the Council. USACE is actively participating in Council Working Groups and is supporting the State, Local, and Tribal Leaders Task Force.

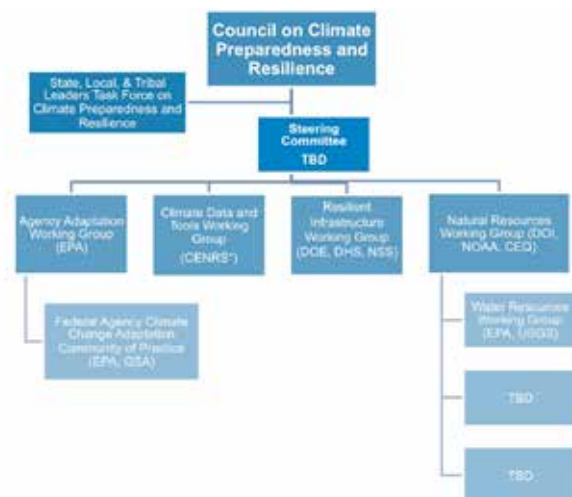


Figure 5. Structure of Council on Climate Preparedness and Resilience (January 2014).

### Federal Agency Adaptation Community of Practice

The Federal Agency Adaptation Community of Practice is a continuation under the new EO 13653 from the ICCATF's Agency Adaptation Processes working group and provides a forum for interagency collaboration on facilities and climate change adaptation. The types of knowledge sharing fostered by the CoP include staff training and capacity building, methods for agencies to evaluate or measure progress, communication strategies, approaches to integrating adaptation into existing programs, and how to apply climate change scientific information in agency decision-making. USACE is a leading member of both the working group and the CoP, and has supported information exchange workshops before and after the CoP began. The types of knowledge sharing fostered by the CoP include staff training and capacity building, how agencies are evaluating or measuring progress, communication strategies, approaches to integrating adaptation into existing programs, concrete examples of agency adaptation projects and results, how to apply climate change scientific information in agency decision making, and providing agency-specific briefings about progress under their plans.

### US Global Change Research Program Adaptation Science Working Group

Since 1990, the U.S. Global Change Research Program (USGCRP) has coordinated and integrated federal research around global changes, including climate change. Though USGCRP has focused primarily on advancing the science of global change, its 2012 Strategic Plan includes explicit new goals for informing decisions related to climate change and climate adaptation, for education and outreach on climate and global change, and on sustaining assessments of the US response to climate change. In 2013, USACE was nominated by the OSTP Subcommittee on Global Change

Research (SGCR) to help lead work under the Informing Decisions strategic goal.

One USGCRP working group working on these high priorities is the Adaptation Science Working Group, co-chaired by USACE since 2012. High priority activities of this working group for USACE are:

- Advancing “actionable science” and evaluation frameworks and measures for adaptation efforts. “Actionable science” is the theory, data, analysis, models, and other tools available, relevant, reliable, and understandable for supporting multiple scales of decision-making around climate adaptation and mitigation questions. Actionable science can support decisions across wide spatial, temporal, and organizational ranges, including those of time-sensitive operational and capital investment decision-making. In many cases, climate science and climate change information must undergo a translation step to maximize its visibility, relevance, and utility for decision-makers to see it as actionable and to use it. The near-term focus is on federal science products and services and the translation of these, where necessary, to be more accessible and more actionable for consistent federal agency decisions around climate adaptation and mitigation.
- Helping to produce and test candidate evaluation frameworks and metrics appropriate for measuring the efficiency and effectiveness of adaptation and mitigation measures, first for federal agencies’ decisions and actions, then for the wider sets of decision makers.

In 2013, USACE staff co-wrote *“Resources for Evaluating and Monitoring Climate Change Adaptation Actions in Coastal Regions: An Annotated Bibliography”*, which is available publicly at the USGCRP web site.





### National Climate Assessment

The National Climate Assessment (NCA) is an important and official resource for understanding and communicating climate change science and impacts in the United States. The Global Change Research Act of 1990 mandates that periodic national climate assessments be conducted. A number of USACE staff have contributed to this 3rd NCA between 2010 and its release in May 2014. They participated in forums and workshops, contributed to technical support reports, served on author teams, helped to shape the ongoing assessment work, provided agency review comments on the draft released for comment in February 2013, and worked to resolve the public comments in the NCA chapters USACE staff served as coauthors on the following NCA chapters: Water Resources, Transportation, and Midwest.

Several of the technical support documents participation have or will be released as interagency reports, including these two, in which USACE participated:

- December 2012, NOAA, the USGS, the Strategic Environmental Research and Development Program (SERDP), and the USACE published NOAA Technical Report OAR CPO-1, *Global Sea Level Rise Scenarios for the United States National Climate Assessment*. This NCA technical support report provides a synthesis of the scientific literature on global sea level rise and a set of four global mean sea level rise scenarios to describe future conditions for the purpose of assessing potential vulnerabilities and impacts.
- *Water Resources Sector Technical Input – Interim Report In Support of the U.S. Global Change Research Program 2014 National Climate Assessment*. This technical input report was commissioned by the USGCRP as input for the Water Resources Chapter of the 2014 National Climate Assessment, is a summary of a larger intergovernmental document being finalized as an interagency report to be published later in 2014.

### Climate Change and Water Working Group

The Climate Change Water Working Group (CCAWWG) is an informal federal agency group that provides engineering and scientific collaboration in support of water management under a changing climate. Founded by USACE, DOI's Reclamation and USGS, and NOAA, CCAWWG has been an effective working-level forum since 2007 among federal agencies that fosters communication, operational, and research partnerships around user needs across the water resources and science communities of practice. CCAWWG now also includes FEMA, Environmental Protection Agency (EPA), the National Atmospheric and Space Administration (NASA), and the US Department of Agriculture (USDA) Agricultural Research Service. Other agencies with interests in water resources also participate (e.g., DOT FHWA). CCAWWG has established a joint web site to provide information on their activities, which include examinations of user needs for climate and weather information for long- (>5 yrs) and short-term water resources planning and management (see inset box).

### Improving Our Knowledge for Water Resources Management and Infrastructure Resilience

USACE is improving our knowledge about climate change impacts and adaptation through the use of targeted pilot studies to test new ideas and develop information needed to develop policy and guidance, assessments of our needs for climate information in decision-making, and developing training to support staff capabilities and foster interagency relationships that will support collaborative networks to address climate challenges and opportunities.



### Pilot Studies

We are in our fifth year of testing methods and frameworks for adapting to climate change through the use of pilot studies. These pilots (see Appendix D for more information) help us develop and test alternative adaptation strategies to

achieve specific business management decisions; identify new policies, methods, and tools to support adaptation for similar cases; learn how to incorporate new and changing climate information throughout the project lifecycle; to develop, test, and improve an agency level adaptation implementation framework; and to implement lessons learned in next pilot phase.



The pilot projects have provided a body of knowledge and tested methods that can be used to successfully adapt projects to projected climate change. The pilots also demonstrate that in many cases, there is sufficient actionable science now to permit assessment of climate change impacts to projects and to support planning and design of measures to adapt to or avoid these impacts. This is a significant advance. Instead of waiting for highly technical adaptation guidance, broad initial policies could reduce the time and cost of adaptation by providing the legal and technical justification for action, narrowing the range of potential alternatives and guiding planning and study approaches to support the desired decisions. Lastly, the pilot projects showed that costs and benefits will change over time, just as climate does. Consideration of dynamic changes over time can guide adaptive management decisions.



## Identifying User Needs for Adaptation

We are also improving knowledge through assessments of our needs for climate information in decision-making in association with agencies having aligned missions and operations. By providing those needs to science agencies, we can help shape science to meet our needs. In 2011, USACE and Reclamation published the report, *Addressing Climate Change in Long-Term Water Resources Planning and Management: User Needs for Improving Tools and Information*. This report builds on the needs identified in USGS Circular 1331 and seeks to focus research and technology efforts to address information and tool gaps needed for longer-term water resources planning and management. The report concluded that there are gaps in the information and tools to help water managers understand how to use climate change information to make decisions, how to assess the responses of natural systems to climate change, and how to communicate the results and uncertainties of climate change to decision-makers. A follow-on report now being prepared by science agencies will present a strategy on how to meet the identified user needs.



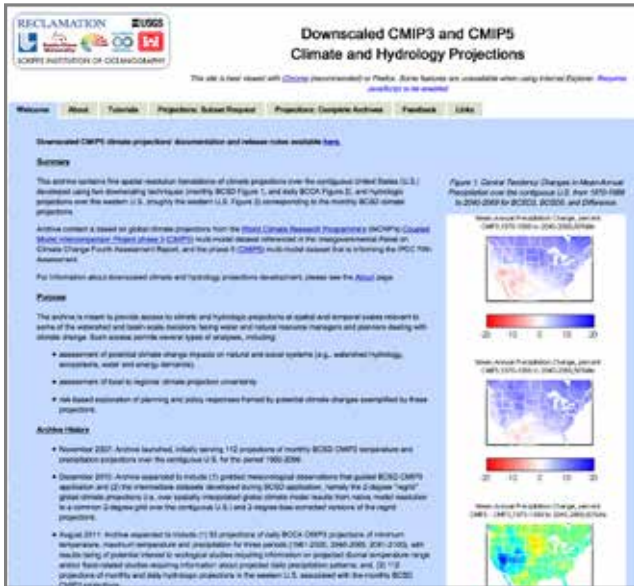
In 2013, CCAWWG members USACE, Reclamation, and NOAA's National Weather Service (NWS) published a report about user needs for weather and climate information for short-term water management decisions. This report (*Short-Term Water Management Decisions: User Needs for Improved Climate, Weather, and Hydrologic Information*) describes short-term water management decision processes within USACE and Reclamation, including how assumptions of climate change and variability influence decisions. The report presents the types of monitoring and forecast information that is available from NWS and other agencies to support water resources management and discusses the characteristics and constraints on the development and use of this information. It will be followed by a science-agency prepared report laying out a strategy to meet the user needs expressed.

## Coupling Science and Engineering

USACE implements its Climate Change Adaptation Policy through close coupling of science and engineering to aggregate and translate science into actionable engineering information supporting adaptation policy and actions. This process allows us to take best advantage of the highly dynamic science of climate and climate change produced by the experts in other agencies, while leveraging and increasing our traditional capabilities in water resources engineering. USACE sets the questions, problems and agenda for this coupled translational work in cooperative partnerships between scientists and engineers across agencies and from academic partners.

USACE, beginning with support from the American Recovery and Reinvestment Act of 2009 (PL 111–5) and continuing with budgeted base funds, joined with Climate Central, Lawrence Livermore National Laboratory (LLNL), Reclamation, Santa Clara University, Scripps Institution

of Oceanography and USGS to create and maintain an archive of climate model outputs post-processed for ease of application to water-resources problems. This *archive* at the LLNL Green Data Oasis site contains climate model projections produced under the WMO CMIP experiments phase 3 and phase 5 downscaled to sub-continental domains for large parts of North America using multiple statistical downscaling methods. The archive also contains hydrologic projections for different domains in North America driven by those climate projections.

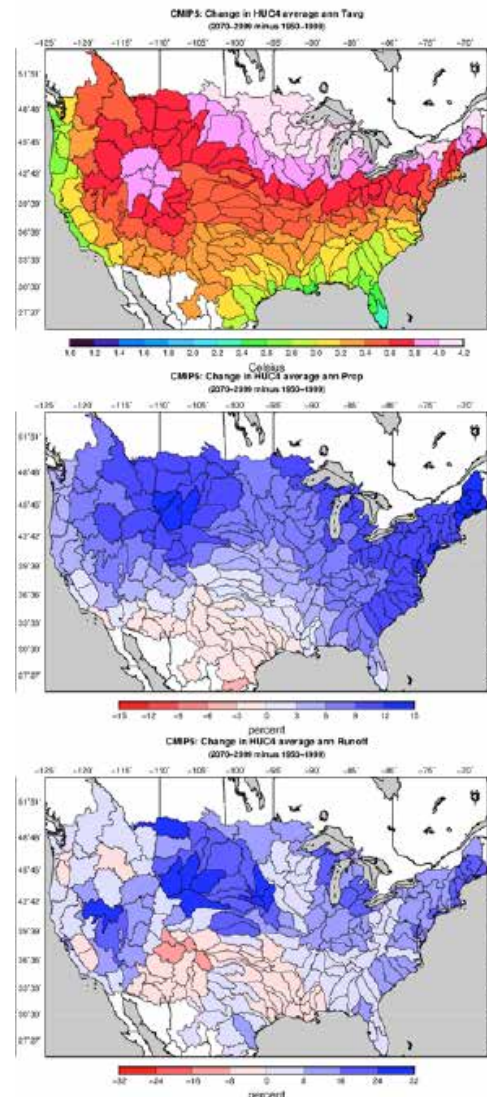


**Figure 6.** Image of web site for the archive of publicly available downscaled climate and hydrology information to support water resources decision-making.

In 2013, this consortium developed downscaled outputs for the CMIP5 data set and compared the results with CMIP3. This complex project has been presented for peer review at well-attended sessions of the American Geophysical Union over the past several years, and will be documented in a series of peer-reviewed journal papers. Sample output is shown in Figure 7 for the 202 USGS Hydrologic Unit Code 4 watersheds in the contiguous US.

### Training to Support Adaptation

CCAWWG agencies USACE and Reclamation are developing climate change and water resources material to be offered by the University Corporation for Atmospheric Research (UCAR) as part of the long-standing and well-regarded COMET Professional Development Series. The title of the climate training series is: “Assessing Natural



**Figure 7.** BCS05 period-mean changes for future period 2070-99 relative to 1950-1999: (top) basin average annual temperature (°C), (middle) basin average annual precipitation (%), (bottom) average annual basin runoff (%)

System Impacts under Climate Change.” The series has been designed and developed to deliver technical training to water resources professionals for incorporating climate science and climate change information with appropriate representations of uncertainties into a variety of natural resource impact assessments. This collaborative team has developed and delivered courses to an array of federal and non federal students whose work includes assessing water resource-related impacts under climate changed conditions. The initial resident courses on understanding hydrology under climate change, and applications for crop irrigation, were created and delivered in 2013. A virtual learning course on hydrology was presented in January 2014. A resident learning course on stream temperature effects has been

developed and will be delivered for the first time in 2014, with a course on river and reservoir sedimentation impacts planned for development and deployment in 2015.



**Figure 8.** Image of web page leading to free, publicly-available training developed by CCAWWG agencies.

These courses are intended to test and help refine the efficiency of different teaching and learning methods and to help inform development of requirements for a sustainable business model to support the future continued delivery and maintenance of this Professional Development Series.

While the resident and virtual learning courses are led by professional instructors, the Reclamation and USACE and COMET team is also developing online, self-directed learning tools based on these courses. The prerequisite course for all residence and virtual courses is one of these self-directed offerings, Preparing Hydro-climate Inputs for Climate Change in Water Resource Planning.

### Climate Change Research and Development

USACE is also conducting research and development on climate change through the activities of its Engineer Research and Development Center (ERDC). The goal of this research is to provide science and technology that will help to sustain missions, protect assets, and ensure viable operations in the

### Examples from USACE-ERDC's Diverse R&D Portfolio

#### *System-Scale Vulnerability Assessment: Project Example — Risk Quantification for Sustaining Coastal Military Installation Assets and Mission Capabilities (Sponsor: DoD's Strategic Environmental Research and Development Program)*

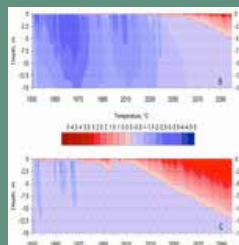


This research project quantitatively evaluates the vulnerability of both installation assets and capabilities threatened by the combination of sea level rise and coastal storms. A multi-tiered approach was developed through regional application in the area of Hampton Roads, Virginia, followed

by detailed analysis of Naval Station Norfolk, VA that:

- Projects potential changes to the coastline under a range of storm and SLR scenarios,
- Simulates hurricanes and quantifies forcings (winds, floodwater levels, and sedimentation),
- Utilizes a critical infrastructure network model,
- Assesses damage to structures, and capabilities given the storm forcings, and
- Quantifies the risks of mission impairment.

#### *Climate Change Processes and Impacts in Cold Regions: Project Example — Addressing Impacts of Climate Change on U.S. Army Alaska (Sponsor: DoD's Strategic Environmental Research and Development Program)*



DoD utilizes 1.5 million acres of land for training in Interior Alaska where future climate scenarios predict a ~5°C increase in mean annual air temperatures over the next 80 years. This warming is expected to degrade permafrost and dramatically affect surface hydrological, soil and vegetation regimes. This research project is integrating the use of field measurements and physical and ecosystem modeling to support risk-based management and planning for training requirements under changing climate and ecological regimes.

“We’re using research and development to explore a range of potential impacts of climate change to our military and civil works assets...By evaluating our natural and engineering systems in the context of future scenarios we’re preparing ourselves in regard to the uncertainties associated with future climatic conditions.”

- Beth Fleming, Ph.D., Director, Environmental Laboratory, Engineer Research and Development Center

face of climate change. ERDC's portfolio of climate change research projects supports both military and Civil Works applications. Science, engineering and technologies are being developed to gain understanding of the consequences of climate change for natural and engineered systems relevant to the military and civil works programs, and to support the development of science-informed adaptation strategies. The research portfolio includes more than 20 projects in four focus areas:

- System-scale vulnerability assessment and risk quantification;
- Climate change processes and impacts in cold regions;
- Ecosystem response modeling to characterize effects on natural systems
- Integrating climate change information with planning and operational practices.

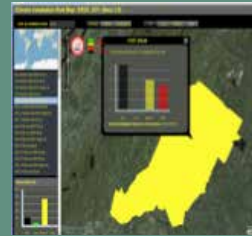
The products of this research provide knowledge about system performance under climate change, new analytical methods, and decision-support tools to support risk management for planning, operations, and maintenance of both civil works projects and military installations threatened by climate change. Tools and techniques to model coastal storm hazards, understand the implications of sea level rise, quantify permafrost loss, characterize infrastructure fragility, predict biome shifts, anticipate threats to endangered species, and monitor changes in contaminant mobility are captured in these studies. These efforts support the capability needed to assess and adapt to climate change threats and address uncertainties through adaptive risk management strategies. The overall goal of this research is to provide deployable science, tools and guidance to the field to support effective climate change adaptation and risk management strategies.

## Developing Policy and Guidance for Infrastructure Resilience

Our goal is to develop practical, nationally consistent, legally justifiable, and cost effective measures, both structural and nonstructural, to reduce vulnerabilities and improve the resilience of our water resources infrastructure impacted by climate change. Here, we categorize policy and guidance for datums, sea level change, and hydrology as example topic areas.

## More Examples from USACE-ERDC's Diverse R&D Portfolio

### *Ecosystem response modeling: Project Example — Climate Change-Induced Biome Shifts (Sponsor- US Army)*

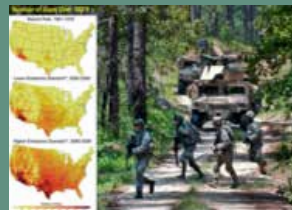


The goal of this research is to assess the environmental repercussions of climate change-induced biome shifts and their potential consequences for military installations. This work utilizes existing regional vegetation dominant biome-shift models to predict significant changes in ecological risk assessment at installations.

A decision support tool has been developed that allows for the consideration of future climate scenarios so that installation managers can evaluate options for minimizing relevant risks posed by climate change.

### **Integrating Climate Change Information with Planning and Operational Practices: Project Example –**

#### *Framework for Implementing Climate Considerations in Established Army Installation Planning Processes (Sponsor: US Army)*



This research effort is developing approaches for incorporating the consideration of climate change information into five major Army installation planning processes: Installation Strategic Plan, Master Plan, Range Complex Master Plan, Integrated Natural Resource

Management Plan, and Critical Infrastructure Risk Management. The project incorporates demonstrations at individual installations and provides recommendations for modifications to practice in order to integrate climate change considerations into installation planning.

## Policy and Guidance for Consistent Vertical Datums

The vertical datum is the base foundation for nearly all civil and military design, engineering, and construction projects in the USACE—especially those civil projects that interface with water. Elevations or depths may be referred to local or regional reference datums. The use of consistent nationwide vertical datums is a fundamental underpinning of adaptation to a changing environment, particularly where the combination of land subsidence and global sea level rise could result in rapidly changing conditions that impact USACE coastal

infrastructure providing coastal storm risk reduction, flood risk reduction, navigation, and ecosystem benefits. In 2006, USACE began working to establish a consistent nationwide datum and subsidence standard to provide a foundation for all activities, but especially in coastal areas where datum conversions can be tricky and subsidence can have a large effect on project elevations. This includes a Comprehensive Evaluation of Project Datums (CEPD) and Compliance Database to ensure that all USACE projects are tied to the correct datum; and if they were not require transition to current vertical datum. This program also developed the USACE Survey Marker Archive Retrieval Tool (U-SMART) Database to store project control information in a standard database referenced to the National Spatial Reference System. Following a number of interim guidance products, in December 2010, USACE published comprehensive guidance in the form of Engineer Regulation 1110-2-8160 *Engineering and Design: Policies for Referencing Project Evaluation Grades To Nationwide Vertical Datums* and Engineer Manual 1110-2-6056, *Standards and Procedures for Referencing Project Evaluation Grades to Nationwide Vertical Datums*. All USACE projects are working to meet a 2014 datum compliance deadline.

### Policy and Guidance for Sea Level Change

USACE has long recognized the potential of changing sea levels to impact our projects. Since 1986, USACE guidance has recognized the need to incorporate changing tide gauge information into planning and design of our projects. Since 2009, we have required the use of three scenarios of potential relative sea level change to be considered in every USACE coastal activity as far inland as the extent of estimated tidal influence. Studies that include backwater profiling should also include potential relative sea-level change in the starting water surface elevation for such profiles, where appropriate. The guidance is used not only throughout USACE, but by other agency partners as well, including the State of Florida. *Engineer Circular (EC) 1165-2-212* is cited as an example of federal policy supporting adaptation planning in several publications (e.g., Tebaldi et al. 2012 and Bierbaum et al. 2012). ECs are intended to be temporary guidance, so EC 1165-2-212 has now been replaced with *Engineering Regulation (ER) 1100-2-8162, Incorporating Sea Level Change in Civil Works Programs*, published in 2013.

The development of sea-level change adaptation planning and implementing guidance was the focus of an interagency and international team that developed USACE Engineering Technical Letter (ETL) 1100-2-1, *Procedures to Evaluate Sea Level Change, Impacts, Responses, and Adaptation*, signed in February 2014. The expert team included representatives from USACE districts, divisions, labs, and centers, and also from NOAA, USGS, Reclamation, US Navy, Coast Guard,

FHWA, FEMA, National Park Service, US Naval Academy, HR Wallingford (UK), University of Southampton (UK), and Moffatt and Nichol Engineers.



This technical adaptation guidance stresses the development of thresholds and tipping points to guide adaptive, flexible adaptation as well as detailed implementation guidance on how to include sea-level change impacts and adaptation into USACE planning, engineering, construction, operation, and maintenance. The guidance integrates the recommended planning and engineering approach at the regional and project level necessary for understanding and adapting to impacts of projected sea-level change. A hierarchy of decisions supports an appropriate level of analysis. Key decision matrix concepts address sustainability, resilience, adaptive and anticipatory planning, and system and cumulative effects.

### Climate Change and Inland Hydrology Guidance

Incorporating climate change considerations within our wide array of inland hydrology guidance is a priority action for USACE. We developed an overarching enabling strategy to address climate impacts to the hydrologic aspects of USACE projects and programs. This approach builds on the core principles of scalable frameworks and scenarios to enable assessments of future project performance against the uncertainties of climate change. The scalable framework requires differing amounts and types of information, level of detail, and complexity of analyses depending on the types of applications under study e.g. there is no 'one size fits all' approach.

Our first hydrology guidance was on climate change considerations for inland hydrology released in May 2014: *Engineering and Construction Bulletin (ECB) 2014-10, Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Design and Projects*. This ECB outlines concepts, goals, and guidance and provides an example of how to incorporate new science and engineering

in hydrologic analyses for new and existing USACE projects. The ECB establishes a procedure to perform a qualitative analysis of potential climate threats and impacts to USACE hydrology-related projects and operations. The method consists of a two phase process that first conducts an initial screening-level qualitative analysis to identify whether climate change is relevant to the project goals or design. If climate change is relevant to the project goals or designs, the second phase requires an evaluation of information gathered about impacts to the important hydrologic variables and the underlying physical processes such as changes in processes governing rainfall runoff or snowmelt. The information should be used to help identify opportunities to reduce potential vulnerabilities and increase resilience as a part of the project's authorized operations and also identify any caveats or particular issues associated with the data. The information gathered in the second phase can be included either in risk registers or separately in a manner consistent with risk characterization in planning and design studies, depending on the project phase.

The uncertainty associated with future climate provides an opportunity to use information from the very distant past to help frame characteristics of flood possibilities. This must be done in a manner that is consistent with USACE mission and goals as well as with considerations for the underlying assumptions associated with paleoflood information. USACE has drafted policy and guidance addressing how and where paleoflood hydrology methods are relevant and appropriate for use in USACE design and operations, including decisions such as estimating flood peak magnitudes, volumes and durations for flood damage assessments, or evaluating design criteria using the minimum essential guidelines. This guidance is expected to be published in 2014.





# MODERNIZING USACE PROGRAMS AND POLICIES TO SUPPORT CLIMATE RESILIENT INVESTMENT

Section 2 of EO 13653 requires federal agencies to work with the CCPR to modernize their programs and policies to support climate-resilient investments at all levels, while ensuring continued protection of public and environmental health. Examples of modernizing actions include identifying, removing, or reforming barriers that discourage investments to increase climate change resilience or that increase the vulnerability of natural and built systems, economic sectors, natural resources, or communities to climate change. This includes developing and encouraging smarter investment strategies for use by states, local communities, and tribes.

As described in the Adaptation Plan above, USACE already has a number of activities underway, guided by Adaptation Steering Committee and supported by O&M Remaining Items Responses to Climate Change (RCC) and IPET, to modernize agency guidance to increase climate change preparedness and resilience. Our new policies, guidance, tools, and methods not only allow us to understand our vulnerabilities, but they support improvements to resilience internally and can assist state, local, and tribal communities as well.

By involving internal and external experts, district, division, lab, center, HQ staff, other agencies, NGOs and the private sector in this process, we support and encourage the transfer of knowledge between our partners and stakeholders at all levels necessary to reduce vulnerability and improve resilience to the effects of climate and extreme weather. Through our work with the State, Local and Tribal leaders Task Force established under Section 7 of EO 13653, USACE is developing an improved understanding of their needs and working to provide solutions as appropriate. The lessons learned from these interactions will help guide the development of USACE policy, guidance, tools, and methods in this critical area.

## EO13653 Section 8: Definitions

**Preparedness:** Actions taken to plan, organize, equip, train, and exercise to build, apply, and sustain the capabilities necessary to prevent, protect against, ameliorate the effects of, respond to, and recover from climate change related damages to life, health, property, livelihoods, ecosystems, and national security

**Adaptation:** Adjustment in natural or human systems in anticipation of or response to a changing environment in a way that effectively uses beneficial opportunities or reduces negative effects

**Resilience:** The ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions



# MANAGING LANDS AND WATERS FOR CLIMATE PREPAREDNESS AND RESILIENCE

Section 3 of EO 13653 requires the heads of the DoD, DOI, USDA, EPA, NOAA, FEMA, USACE, and other agencies as recommended by the Council to complete an inventory and assessment of proposed and completed changes to their land- and water-related policies, programs, and regulations necessary to make the Nation's watersheds, natural resources, and ecosystems, and the communities and economies that depend on them, more resilient in the face of a changing climate.

USACE participates in the Climate Natural Resources Working Group established to support the Council meet its Section 3 goal to better manage lands and waters for climate preparedness and resilience. As we have been for several years now, USACE is assessing our land-and water-related policies programs and activities with respect to climate preparedness and resilience. This information will serve as the foundation for developing an inventory of proposed and completed changes we plan to take, as detailed in the report to the Council required under Section 3 of EO 13653, and also to help us prioritize our adaptation planning and implementation.

As part of this effort, the EO suggests a greater focus on program and policy adjustments that promote the dual goals of greater climate resilience and carbon sequestration. USACE civil works projects contribute significantly to carbon sequestration, primarily through the long-term burial of organic carbon. USACE manages over 20 million acres and reservoirs that have the potential to sequester more carbon per unit area than any other sites in the biosphere. USACE is the predominant manager/steward of waterways and reservoir systems across the nation and can play a major role in climate change mitigation measures. USACE has been considering the linkages between our land and water resources and carbon sequestration and the effect of climate change on potentials for carbon sequestration. The two ongoing projects described here are examples of how we have been working to couple science and engineering to support the development

of policy, guidance, tools, and methods that meet these dual goals. Both projects inform our Civil Works and Military Missions programs.

- **Itemization of Carbon Sources and Sinks in Interior Alaska:** To assist land managers in adapting and managing for potential changes in the Interior Alaska carbon cycle we have developed an assessment that incorporates an overview of the climate, ecosystem processes, vegetation types, and soil regimes in Interior Alaska. The main focus is on how climate change impacts the carbon cycle. Our objective is to provide a synthesis of the most current carbon storage estimates and measurements to guide policy and land management decisions on how to best manage carbon sources and sinks in Interior Alaska. The results of this study can be used for carbon cycle management in other locations within the boreal biome which encompasses a broad distribution from 45° to 83° north.

The carbon sequestration work at USACE supports technical field analyses and is part of a broader USACE response to EOs 13514 and 13653. It requires all federal agencies to estimate, report, and begin to control their emissions, including emissions from lands they control. While not yet required to report land emissions or potentials for sequestration, it is important to consider the mass balance of fossil energy use, carbon-free energy production, and carbon sequestration potential on federal

managed lands and waters. The land cover modeling approach developed by USACE and partners at USGS and in academia is quite general and may be applicable to a wide range of public and private lands.

- **Carbon Sequestration Assessment Pilots:** We initiated a carbon sequestration disturbance study encompassing diverse climate, land cover, and land use characteristics relevant to carbon sequestration and emission sources as well as variable disturbance regimes and response characteristics. The project addresses common disturbances such as drought, floods, hurricanes, land cover change, fire, and coarse-scale insect outbreaks in terms of their potential effects on carbon itemization efforts.

Our approach is to use existing information to provide rapidly a first quantitative estimate of carbon sequestration and carbon sequestration potential on lands and in aquatic systems operated or managed by USACE. Careful examination of the scientific literature and an assessment of relevant information available for USACE databases indicated that, within strict time constraints, the only viable option for a broad area assessment was to use statistical approaches to extrapolate empirical sequestration relations developed from a few locations to the broad population of USACE project sites.

The FY12 work on the second project consisted of a pilot study that 1) developed rapid assessment techniques based on established science and existing information and then 2) applied the developed techniques to a selected sub-set of USACE civil works projects. Phase II (FY13) included expansion of the Phase I work to include the New England, Omaha, and Savannah districts, enhancements to the data and models used for terrestrial and aquatic assessment, more explicit linkage of the aquatic assessment model to project watersheds, and initial efforts to incorporate environmental disturbance effects into the assessment. Particularly significant to managers and decision makers for USACE Civil Works projects is the additional level of uncertainty that environmental disturbances may introduce and how disturbance-driven changes in normal (i.e., baseline) operations may propagate to changes in carbon sequestration.

Ecosystem disturbance can affect land use, land utility, and carbon storage potential of lands at a variety of spatial scales ranging from the wide swaths of areas affected by insects or drought conditions to the smaller areas affected by fire, flooding, or hurricanes. Disturbances also occur over broad time scales from the almost sudden generation of flood conditions following extreme storms to the decadal patterns of climate warming or drought impacts. In addition,

the response of ecosystems or landscapes to disturbances can be complicated because multiple disturbances can occur over space and time. Drought and insect damage can increase the biomass of standing dead trees and this can lead to larger or more severe fires. Land cover change, whether human or climate change driven, can affect the way ecosystems respond to disturbances or how long post-disturbance recovery takes. Due to this wide variety of drivers and responses to disturbance over space and time there is no way to address all combinations of effects of disturbance across broad land areas. However, by identifying the most likely disturbance activities that would be expected to affect specific physiographic locations we can start to isolate and predict the way ecosystems will respond to disturbance. When ecosystem change or transitions can be keyed to carbon storage, fluxes, or processes, we can start to predict how landscape change from disturbance will affect the carbon storage capacity of the landscape.

Some disturbances, like flooding, drought, and land cover change could affect all three of the districts. Other disturbances, like hurricanes, fire, and insect damage, only affect specific regions of the United States and thus the districts in those regions. We focused our efforts on these six disturbances by identifying what geospatial information is available for estimating their areal extent, temporal history, and where possible, to identify trends in the magnitude and areas affected by the six disturbances. Then we searched for relevant peer-reviewed literature that could provide insight into drivers for the disturbances and potential feedbacks or responses to disturbance.

Both projects include partners and stakeholders. The lessons learned from these projects will help guide the development of USACE policy, guidance, tools, and methods in this critical area.



# PROVIDING INFORMATION, DATA, AND TOOLS FOR CLIMATE CHANGE PREPAREDNESS AND RESILIENCE

Section 4 of EO 13653 requires a group of federal agencies to work together to develop and provide authoritative, easily accessible, usable, and timely data, information, and decision-support tools on climate preparedness and resilience to support federal, regional, state, local, tribal, private-sector and nonprofit-sector efforts to prepare for the impacts of climate change. Named agencies include the DoD, DOI, USDA, US Department of Commerce (DOC), US Department of Health and Human Service (HHS), US Department of Housing and Urban Development (HUD), DOT, US Department of Energy (DOE), DHS, EPA, NASA, and any other agencies recommended by the Council. This activity will support CEQ, the Office of Science and Technology Policy (OSTP), and OMB as they oversee the development of a web-based portal on data.gov consistent with EO 13642 (Making Open and Machine Readable the New Default for Government Information).

USACE is committed to continuing to share information, data, and tools for climate change preparedness and resilience, and is supporting the Council's Climate Data and Tools Working Group. Examples of sharing information, data, and tools for climate change preparedness and resilience include our various [sea level change calculators](#), interagency support and collaboration to produce [Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections](#), the [Sea Level Rise Tool for Sandy Recovery](#), teams performing climate-related R&D for the Strategic Research and Development Program, and our climate training series: *Assessing Natural System Impacts under Climate Change*. These collaborative relationships dealing with Civil Works also enhance our military support missions and provide valuable information about climate preparedness and resilience useful in stability operations.

The [Building Strong Collaborative Relationships for a Sustainable Water Resources Future](#) program, is an example of a pre-existing collaborative activity in which we have initiated and encouraged collaboration around water resources management at all levels of government, with academia, with the private sector, and with the public. As a result of this program, we have developed [Federal Support Toolbox](#), a comprehensive “one-stop-shop” online water resources data portal with direct links to valuable data, state of the art models and tools for utilization in information sharing and collaboration for the water resources community in the U.S. and internationally providing to water resources management programs, databases and models created by the U.S. federal government, states, tribal nations and non-governmental organizations. Some of these tools are directly applicable to the Council's Climate Data and Tools Working Group.



# PLANNING FOR CLIMATE CHANGE RELATED RISK

The USACE Adaptation Plan describes activities underway to evaluate the most significant climate change related risks to, and vulnerabilities in, agency operations and missions in both the short and long term, and outlines actions that we are taking to manage these risks and vulnerabilities (see Progress). Our vulnerability assessments support the identification and assessment of climate change related impacts on, and risks to, our ability to accomplish our missions, operations, and programs. The Plan contains a description of programs, policies, and plans USACE has already put in place, as well as additional actions the we will take, to help us manage climate risks in the near term and build resilience in the short and long term. We are continuing to develop, implement, and update comprehensive plans that integrate consideration of climate change into agency operations and overall mission objectives. These plans have been submitted to CEQ and OMB for review in June 2011, 2012, 2013, and March 2014.

Pursuant to Section 5 of EO 13653, this June 2014 Adaptation Plan reports that USACE has not yet identified a climate risk during the adaptation planning process that is deemed so significant that it impairs USACE's statutory missions or the operations addressed.

USACE has been actively considering the need to improve climate adaptation and resilience, including the costs and benefits of such improvement, with respect to agency suppliers, supply chain, real property investments, and capital equipment purchases, including the costs and benefits of such improvement.

An initial assessment indicates that, different from many other agencies, USACE could experience climate change-related supply chain issues from the customer side and from the supply side. For example, potential customer-side supply chain issues include:

- disruptions to necessary equipment, supplies, and resources supporting large construction projects (including dredging and beach renourishment) due to adverse conditions caused by extreme events (e.g., drought, flood, tornado, earthquake, ice storm) or economic conditions (e.g., strike, recession)
- disruptions to power necessary to support operations of locks, dams, canals, pumps, hurricane barriers and other gated structures, and support critical management functions such as emergency operations and water control management systems;

As a provider of inland and maritime navigation services, USACE could face potential supply-side supply chain issues including:

- disruption of inland/maritime navigation due to equipment failure or accidents (e.g., loose barge impacting lock and dam structural integrity or performance, oil spill in navigable waterway).

Following publication of USGS Circular 1331 in 2009, USACE recognized that mismatch of water supply and demand would be a critical issue for our Civil Works Mission. As a result, we began two efforts supporting planning for climate-related risk: an assessment of the current status of our Drought Contingency Plans (DCPs) with recommendations on how to update these to account for future climate impacts, and an assessment of the current state of reservoir sediment, including an assessment of potential future climate impacts and development of a strategy to identify reservoirs at risk of increased sediment delivery. Since 2009, we have conducted several adaptation pilots to learn and test methods supporting each of these efforts (see Appendix D, pilot projects 2, 4, 8, 10, 11, 12, and 13).

The DCP effort has compiled and assessed 142 DCPs covering 301 USACE projects. The team established a geospatial portal to document, store, and disseminate information relative to droughts and drought contingency plans, including a complete library of digitized DCPs and summaries of each. Using information from the downscaled climate projection data and hydrologic simulations that USACE helped to develop (described above under the Coupling Science and Engineering section), we intend to use the same sets of projections for helping characterize specific drought threats to different regions of USACE operations. Updated policy and guidance regarding DCP updates to account for climate change is a planned product of this effort.

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# INTERNATIONAL LEADERSHIP FOR CLIMATE PREPAREDNESS

International leadership supporting climate preparedness one of the three key pillars of the PCAP released in June 2013. Through its Civil Works and Military Programs support activities, USACE is quite active internationally in water resources management, a key sector impacted by climate change. For example, the International Center for Integrated Water Resources Management (ICIWaRM) is a UNESCO Category 2 water center headquartered at the USACE Institute for Water Resources (IWR) in Alexandria, Virginia, USA. ICIWaRM was officially created by an agreement between the U.S. Government and UNESCO in October 2009 to advance the science and practice of integrated water resources management (IWRM) to address water security and other water-related challenges.

## **International Leadership and Collaboration** **Work with International Organizations**

USACE is actively engaged with the World Association for Waterborne Transport Infrastructure (PIANC), which provides a large technical forum for addressing issues relevant to the international navigation community. PIANC established its Permanent Task Group for Climate Change (PTGCC) in 2010, a group that has been chaired by USACE representatives since its inception. The PTGCC includes technical experts and representatives from more than a dozen countries. The mission of the Task Group is inform the international navigation community about the implications of climate change for the sector and where and how adaptation and mitigation actions can be taken. In 2008, the PIANC published the Task Group's review of climate change drivers, impacts, responses, and mitigation (PIANC, 2008) and is currently focusing its efforts on adaptation measures.

## **Alliance for Global Water Adaptation**

USACE plays a leading role, along with the World Bank and Conservation International, in the Alliance for Global Water Adaptation (AGWA), an international consortium focused on developing practical guidance for planning and design decision-making in the face of climate uncertainty.

The AGWA method combines traditional approaches for planning and design with a 'decision scaling' approach. The goal is to work with stakeholders to first assess system vulnerabilities to changes in climate parameters and additional stressors (e.g., population growth, development). Given the vulnerabilities, water managers can then evaluate the observed and projected climate information to develop adaptation strategies that are reflective of the vulnerability of the system and the level of confidence in the available information. USACE currently collaborates with the U.S. Agency for International Development (USAID)'s Mekong-Building Climate Resilience in Asian Cities (MBRACE) program on AGWA pilot studies in Thailand and Vietnam.

## **Engagement with NATO**

USACE scientists and engineers have supported North Atlantic Treaty Organization's (NATO) efforts to foster international collaboration on climate change adaptation and sustainability by organizing technical workshops that have brought together experts from many different countries to consider challenges and potential solutions. In 2010, USACE led a NATO-sponsored workshop that considered climate change adaptation in the context of national security implications relevant to both coastal and inland environments

(Linkov and Bridges, 2011). This was followed by a second NATO-sponsored event focused on sustainable cities and military installations that brought together participants from 15 countries representing multiple fields of expertise. The effort was focused on approaches and tools to inform how military installations and small cities can integrate energy, water, and infrastructure sustainability strategies into management plans that consider threats posed by climate change (Linkov 2014).

### International Support to the US Military

In order to assess, interpret, plan for and mitigate impact from climate change, USACE personnel are working with US Combatant Commands (COCOMs) and select countries. The objectives of these efforts is to collaborate with host countries in the transition of existing science and engineering tools to support vulnerability assessments in order to develop an understanding of potential impacts that is sufficient to inform adaptation planning. USACE scientists and engineers collaborated with the United States European Command to conduct a technology demonstration in Bulgaria in 2013 that included hydrological modeling, geospatial tools for visualizing climate change impacts, and socio-cultural aspects of water security; participants included scientists, engineers, policy makers, and military officials from Bulgaria and Hungary.

A related effort is also underway with the United States Africa Command. The US Army is supporting efforts by USACE scientists and engineers to work with African nations, including Gabon, Ghana, South Africa, Namibia, and Botswana, to develop approaches for measuring adaptive capacity. These researchers are combining quantitative and qualitative methodologies to understand human induced response to climatic and environmental change. Other efforts address issues in the Pacific and Central Asia regions.

USACE personnel in concert with PACOM have been working with Asian countries (Thailand, Cambodia, Vietnam, Lao PDR, Myanmar and Mongolia) to increase capacity of the region to manage changes to water availability brought about through climate change. A series of workshops and meetings have brought national experts from across the region together for training on how to manage water resources and incorporate change in a multinational environment. Broadly the region is asking for guidance from the USACE that address long term public engagement and inclusion of broad stakeholder groups and how to prioritize investments in water management infrastructure so that regional stability is maintained. The result has been continued request for regional governments USACE engagement on climate change and water resource management in the region.



**Figure 10.** Participants from the 2012 Strategic Scenario Planning Workshop for Integrated Water Resources Development in the Lower Mekong Basin held in Bangkok, Thailand. USACE is providing technical support to the Mekong River Commission related to hydropower, fish passages, and river engineering and integrated water resource management. The Mekong River and basin are undergoing 11 planned dams across the mainstem of the Mekong, with the first being built in Laos. These dams have potentially significant environmental and socio-economic impacts to the region especially to the most vulnerable populations that rely on the Mekong River for food and employment.

AFRICOM is supporting efforts by USACE scientists and engineers to work with African nations, including Gabon, Ghana, South Africa, Namibia, and Botswana, to develop approaches to integrate environmental security with human security. USACE researchers are developing tools, tactics and procedures to better understand the relationship between degraded environments and conflict. By developing holistic assessment tools to untangle historic and current vulnerabilities within the environment, these tools provide the foundation for civil-military units to better understand how future climatic change could affect stability. Related efforts include participation in COCOM theater security cooperation programs focusing on increasing access to climate, environment and human security data. In this manner, USACE research on climate change risks become force multipliers for future theater security cooperation efforts.



# REPORT OF PROGRESS TO MAINSTREAM CLIMATE ADAPTATION

USACE has been working for seven years now to identify what we know, what we don't know, and what we can do to fill the knowledge gaps and develop the policy and guidance we need to adapt to climate change. We are analyzing our vulnerability to climate change, including identification of risks and opportunities, and continue to refine these analyses. We understand that our Civil Works and Military Missions activities occur in a dynamic and evolving system, and that the conditions within which we operate can change continuously over time (rather than achieving and maintaining a single equilibrium state). Our experience with “wicked” problems in both our Civil Works and Military Missions has shown us that we must be careful when we implement changes, because our incomplete understanding increases the potential for unintended consequences resulting from actions taken in isolation.

We understand the complexities of adaptation because our water resources engineers and managers — and our military staff — are already accustomed to making decisions under deep uncertainty of the kind that climate change brings. It is precisely this engineering ability to adapt to changing problems and conditions that provides a source of institutional and organizational resilience and experience to guide our climate change adaptation. For example, USACE made many difficult choices during the floods of 2011 in the interests of public safety — choices that were possible only because engineers in the 1920s and 1930s understood that future could bring changing conditions — and they designed options into the system that allowed us to adapt to these conditions.

## **Progress in the Context of the Flexible Framework for Adaptation**

### **Highlights**

Our progress to date to support mainstreaming climate change adaptation has focused on clarifying our adaptation mission and goals and developing new policy and guidance

to support adaptation implementation at multiple scales, from project-specific to nationwide. We are applying our strategic approaches to the priority areas identified in previous years, with a heavy emphasis on external collaboration and pilot tests to help improve our knowledge so we can make progress on the policy and guidance needed to mainstream adaptation.

USACE progress on adaptation is presented below in the context of the CEQ flexible framework for adaptation (Fig 4). All of these activities build awareness and skills within the USACE and for our partners and stakeholders.

### **Selected Examples of Mainstreaming Adaptation**

USACE has been working to mainstream climate change adaptation for several years so that adaptation is integrated into policy, budget, engineering design, implementation and ongoing evaluation in a way that establishes adaptation as standard practice. Adaptation encompasses a continuum of actions that may progress in a linear fashion, may involve iteration, or may end without implementation.



**Figure 11.** CEQ's flexible framework for adaptation.

Examples of adaptation actions include understanding climate change impacts, assessing vulnerabilities to climate, planning various responses, engineering design of adaptation measures, and implementing adaptation. Decisions made at each step are adaptation decisions – a physical or operational change is not the only appropriate end point when mainstreaming adaptation. Example projects of where and how adaptation has been integrated into the USACE are presented here. These are both coastal and inland projects. The distinction is important because there is existing guidance supporting planning and design for coastal projects, whereas for riverine projects, guidance is not yet available.

- Neuse River Basin, NC alternatives were formulated on the historic rate of sea level rise and sensitivity analyses were conducted for the other curves. As a result, the rock sill design height is set to account for some accelerated sea level rise. Under the low and intermediate scenarios, the sill remains functional. Under the high scenario, the sill would still function as desired, but at a reduced level as higher sea levels occur.
- Walton County, FL project includes adaptation to changing sea levels through the beach renourishment cycle.
- The Fargo-Moorhead Metropolitan Area Flood Risk Management study used an interagency and academic Expert Opinion Elicitation (EOE) panel to develop a statistical approach to incorporate climate variability into the discharge-frequency curve for Fargo. The EOE was conducted using the technical guide for use of EOE developed by the Risk Management Center. The EOE identified a change in hydrology. The hydrologic information developed through this process is used in the on-going Red River Basin Feasibility study, which is developing detailed hydrologic and hydraulic models to determine the impact of various flood storage alternatives.
- Jacksonville Harbor Mile Point, FL found that the potential effects of sea level rise would be much less severe under the with-project condition. The selected plan was the only alternative capable of addressing and successfully improving the direction of the water flowing out of the Intracoastal Waterway under the existing tidal conditions while retaining adaptive capacity to preserve performance under future sea level scenarios.
- The climate change and modeling data for an analysis of sediment impacts to Cochiti Dam and Lake is being used in several ongoing studies in the Albuquerque district:
  - Santa Clara Pueblo Watershed Assessment (Section 203) considers observed climate trends and projected climate changes to address likely future changes to watershed hydrology on the Pueblo's lands, with particular attention to flood risk and water resources development at the Pueblo.
  - Española, NM (General Investigation) includes climate trends and projected climate projections in planning sustainable ecosystem restoration for flood risk reduction and watershed management restoration for three Tribes in the Española region of northern New Mexico.
  - Middle Rio Grande Endangered Species Collaborative Program: Under the CESP Collaborative Program Authority, the district is collecting and disseminating information on regional climate trends and future climate projections to the 16 member agencies of the Collaborative Program to inform ecosystem restoration projects required by the USFWS Middle Rio Grande Water Operations Biological Opinion (2003).
- The Great Lakes and Ohio River division Water Management staff has been participating on a task team appointed by the International Joint Commission (IJC) to address future extreme water levels in the Great Lake-St. Lawrence River system. That task team has recently released a draft Adaptive Management Plan for public review and comment and by the end of May 2013 will be submitting a final version of the Adaptive Management Plan to the IJC for consideration. This bi-national Adaptive Management Plan responds to changing climate and the limited ability to alter lake levels through regulation of flows from Lake Superior and Lake Ontario.



# SUMMARY AND CONCLUSIONS

The US Army Corps of Engineers (USACE) understands that climate change is among the major challenges of the 21st century and can impact all areas of our missions and operations. For more than seven years now, we have made progress on a comprehensive approach to climate change that incorporates new knowledge and changing conditions about vulnerabilities, risks, and opportunities into our missions, operations, programs, and projects. Our approach enhances the capacity of our planning, design, construction, operations, and maintenance to adapt to changing climate and other global changes.

Our goal is to develop practical, nationally consistent, legally justifiable, and cost effective measures, both structural and nonstructural, to reduce vulnerabilities and improve the resilience of our water resources infrastructure and military support missions impacted by climate change. We are taking a collaborative approach that takes advantage of different perspectives and expertise so that our progress on adaptation reflects the best available and actionable science. But in turn, we are working to help guide the science to better meet our needs and the needs of other land and water resources agencies.

The June 2014 *USACE Climate Change Adaptation Plan and Report* provides the information requested by the Council on Environmental Quality in the guidance on *Preparing Federal Agency Climate Change Adaptation Plans In Accordance with Executive Order 13653* issued in December 2013. The Adaptation Plan also meets the criteria set out in the *Implementing Instructions for Federal Agency Climate Change Adaptation* issued on March 4, 2011.

We believe that this June 2014 *USACE Adaptation Plan and Report*, prepared at the direction of the USACE Adaptation Steering Committee, demonstrates a broad understanding of the challenges posed by climate change to our mission, programs, and operations, and a commitment to undertake specific actions in FY 2014 and beyond to better understand

and address those risks and opportunities. We present information about how we plan and evaluate agency adaptation planning, describe programmatic activities supporting climate change adaptation, and describe efforts to both better understand and to address climate change risks and opportunities. We are pilot-testing adaptation methods, sharing lessons learned within and outside the agency, and refining our adaptation based on the new knowledge. Working within a risk-informed framework that considers all of the challenges facing us will enable USACE to implement integrated water resources management solutions to the impacts of climate change.

This document also provides additional information on current USACE adaptation planning and implementation progress. The scope, collaboration, and resources we have applied to understand climate change and make progress on adaptation planning and implementation. Our work demonstrates the importance we place on this critical challenge to the long-term sustainability of our mission, operations, programs and projects. This report has shown how crucial this work is to the continued success of USACE in its mission to manage water resources in the US and contribute engineering solutions around the world.



## REFERENCES

Administration of the White House (US). National ocean policy implementation plan [Internet]. Washington (DC): Administration of the White House (US); [cited 2014 May 09]. Available from: <http://www.whitehouse.gov/administration/eop/oceans/implementationplan>

Berry L, Arockiasamy M, Bloetscher F, Kaisar E, Rodriguez-Seda J, Scarlatos P, Teegavarparu R, Hernandez-Hammer NM. Development of a methodology for the assessment of sea level rise impacts on Florida's transportation modes and infrastructure [Internet]. Tallahassee (FL): Florida Department of Transportation; 2012 [cited 2014 May 09]; 148 p. Available from: [http://www.dot.state.fl.us/research-center/Completed\\_Proj/Summary\\_PL/FDOT\\_BDK79\\_977-01\\_rpt.pdf](http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_PL/FDOT_BDK79_977-01_rpt.pdf)

Bierbaum R, Smith JB, Lee A, Blair M, Carter L, Chapin FS, Fleming P, Ruffo S, Stults M, McNeeley S, et al. A comprehensive review of climate adaptation in the United States: more than before, but less than needed. *Mitig Adapt Strateg Glob Change*. 2012;18(3):361-406.

Brekke LD, Kiang JE, Olsen JR, Pulwarty RS, Raff DA, Turnipseed DP, Webb RS, White KD. Climate change and water resources management: a federal perspective. USGS Circ 1331 [Internet]. 2009 [cited 2014 May 05]; 65 p. Available from: <http://pubs.usgs.gov/circ/1331/>

Brekke LD, Kiang JE, Olsen JR, Pulwarty RS, Raff DA, Turnipseed DP, Webb RS, White KD. Climate change and water resources management: a federal perspective. USGS Circ 1331 [Internet]. Climate Change and Water Working Group; 2009 [cited 2014 May 05]. Available from: <http://www.ccawwg.us/index.php/activities/usgs-circular-1331>

Brekke LD, White K, Olsen JR, Townsley E, Williams D, Hanbali F, Hennig C, Brown C, Raff D, Wittler R. Addressing climate change in long-term water resources management:

user priorities for improving tools and information [Internet]. U.S. Army Corps of Engineers Civil Works Technical Series CWTS-10-02. Washington (DC): US Army Corps of Engineers, US Department of the Interior. January 2011 [modified 2011 Apr 24; cited 2014 May 09]; 160 p. Available from: [http://www.ccawwg.us/docs/Long\\_Term\\_Addressing\\_Climate\\_Change.pdf](http://www.ccawwg.us/docs/Long_Term_Addressing_Climate_Change.pdf)

Bureau of Reclamation, Climate Analytics Group, Climate Central, Lawrence Livermore National Laboratory, Santa Clara University, Scripps Institution of Oceanography, U.S. Army Corps of Engineers, and U.S. Geological Survey. Downscaled CMIP3 and CMIP5 climate and hydrology projections [Internet]. Lawrence Livermore National Laboratory; revised April 6, 2014 [cited 2014 June 11]. Available from: [http://gdo-dcp.ucllnl.org/downscaled\\_cmip\\_projections/dcpInterface.html](http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/dcpInterface.html)

Climate Program Office. NOAA Technical Report OAR CPO-1. Global sea level rise scenarios for the United States national climate assessment [Internet]. December 6, 2012 [cited 2014 June 11]. Available from: <http://cpo.noaa.gov/Home/AllNews/TabId/315/ArtMid/668/ArticleID/80/Global-Sea-Level-Rise-Scenarios-for-the-United-States-National-Climate-Assessment.aspx>

Council on Environmental Quality (US) and Office of Management and Budget (US). Implementing instructions for federal agency climate change adaptation. Washington (DC): Council on Environmental Quality (US); 2011 Mar 4 [cited 2014 May 09]; 5 p. Available from: [http://www.whitehouse.gov/sites/default/files/microsites/ceq/adaptation\\_final\\_implementing\\_instructions\\_3\\_3.pdf](http://www.whitehouse.gov/sites/default/files/microsites/ceq/adaptation_final_implementing_instructions_3_3.pdf)

Council on Environmental Quality (US). Federal agency climate change adaptation planning support document [Internet]. Washington (DC): Council on Environmental

Quality (US); 2011 Mar 4 [cited 2014 May 09]; 62 p. Available from: [http://www.whitehouse.gov/sites/default/files/microsites/ceq/adaptation\\_support\\_document\\_3\\_3.pdf](http://www.whitehouse.gov/sites/default/files/microsites/ceq/adaptation_support_document_3_3.pdf)

Council on Environmental Quality (US). Progress report of the interagency climate change adaptation task force: recommended actions in support of a national climate change adaptation strategy: October 5, 2010 [Internet]. Washington (DC): Council on Environmental Quality (US); 2010 Oct 5 [cited 2014 May 09]; 72 p. Available from: <http://www.whitehouse.gov/sites/default/files/microsites/ceq/Interagency-Climate-Change-Adaptation-Progress-Report.pdf>

Executive Office of the President Council on Environmental Quality. Obama administration announces winners of 2013 GreenGov presidential awards [Internet]. Washington (DC): The Executive Office of the President Council on Environmental Quality; November 5, 2013 [cited 2014 June 11]. Available from: <https://www.fedcenter.gov/admin/itemattachment.cfm?attachmentid=767>

Executive Office of the President (US). Federal leadership in environmental, energy, and economic performance. Fed Register [Internet]. 2009 Oct 08 [cited 2014 May 06]; 74(194):52117-52127. Available from: <http://www.gpo.gov/fdsys/pkg/FR-2009-10-08/pdf/E9-24518.pdf>

Executive Office of the President. Preparing the United States for the impacts of climate change, Executive Order 13653 of November 1, 2013 [Internet]. Washington (DC): Federal Register; November 1, 2013 [cited 2014 June 11]. Available from: <https://www.federalregister.gov/articles/2013/11/06/2013-26785/preparing-the-united-states-for-the-impacts-of-climate-change>

Executive Office of the President. The president's climate action plan [Internet]. Washington (DC): The Executive Office of the President; June, 2013 [cited 2014 June 11]. Available from: <http://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf>

Executive Order 13514 of October 5, 2009. Federal leadership in environmental, energy, and economic performance. Federal Register [Internet]. October 8, 2009 [cited 2014 June 11]; 74(194) 1-11. Available from: <http://www.gpo.gov/fdsys/pkg/FR-2009-10-08/pdf/E9-24518.pdf>

Federal Facilities Environmental Stewardship and Compliance Assistance Center. Climate change adaptation [Internet]. [cited 2014 June 11]. Available from: <https://www.fedcenter.gov/programs/climate/>

Interagency Climate Change Adaptation Task Force (US). National action plan: priorities for managing freshwater resources in a changing climate [Internet]. Washington (DC): Interagency Climate Change Adaptation Task Force (US); 2011 [cited 2014 May 09]; 76 p. Available from: [http://www.whitehouse.gov/sites/default/files/microsites/ceq/2011\\_national\\_action\\_plan.pdf](http://www.whitehouse.gov/sites/default/files/microsites/ceq/2011_national_action_plan.pdf)

Interagency Performance Evaluation Team (US). Performance Evaluation of the New Orleans and Southeast Louisiana Hurricane Protection System Final Report of the Interagency Performance Evaluation Task Force [Internet]. Washington (DC): US Army Corps of Engineers; 2006 Jun 1 [cited 2014 May 09]. Available from: <http://permanent.access.gpo.gov/lps71007/>

Kiang JE, Olsen JR, Waskom RM. Introduction to the featured collection on "Nonstationarity, hydrologic frequency analysis, and water management." Journal of the American Water Resources Association. 2011;47(3):433-435.

Kundzewicz ZW, Mata LJ, Arnell NW, Doll P, Jimenez B, Miller K, Oki T, Sen Z, Shiklomanov I. The implications of projected climate change for freshwater resources and their management. Hydrolog Sci J. 2008;53(1):3-10.

Lavers DA, Villarini G. Atmospheric rivers and flooding over the central United States. J Climate. 2013;26(20):7829-7836.

Lavers DA, Villarini G. Were global numerical weather prediction systems capable of forecasting the extreme Colorado rainfall of 9-16 September 2013? Geophys Res Lett. 2013;40(24):6405-6410.

Milly PCD, Betancourt J, Falkenmark M, Hirsch RM, Kundzewicz ZW, Lettenmaier DP, Stouffer RJ. Stationarity is dead: whither water management? Science. 2008;319(5863):573-574.

National Academy of Public Administration. Prioritizing America's water resources investments: budget reform for civil works constructions projects at the US Army Corps of Engineers [Internet]. Washington (DC): National Academy of Public Administration; 2007 [cited 2014 May 09]; 29 p. Available from: <http://www.napawash.org/wp-content/uploads/2007/07-05.pdf>

National Ocean Council. National Ocean Policy Implementation Plan Appendix [Internet]. National Ocean Council; April 2013 [cited 2014 June 23]. Available from: [http://www.whitehouse.gov/sites/default/files/national\\_ocean\\_policy\\_ip\\_appendix.pdf](http://www.whitehouse.gov/sites/default/files/national_ocean_policy_ip_appendix.pdf)

National Research Council. Responding to changes in sea level: engineering implications. Washington (DC): The National Academies Press; 1987.

NOAA Coastal Services Center. Infrastructure systems rebuilding principals [Internet]. Washington (DC): Digital Coast NOAA Coastal Services Center; February 28, 2013 [cited 2014 June 11]. Available from: <http://csc.noaa.gov/digitalcoast/sites/default/files/files/publications/04062013/InfrastructureSystemsRebuildingPrinciples.pdf>

Patterson LA, Lutz B, Doyle MW. Characterization of drought in the South Atlantic, United States. J Am Water Resour As. 2013;49(6):1385-1397.

Patterson LA, Lutz B, Doyle MW. Climate and direct human contributions to changes in mean annual streamflow in the South Atlantic, USA. Water Resour Res. 2013;49(11):7278-7291.

Patterson LA, Lutz B, Doyle MW. Streamflow changes in the South Atlantic, United States during the mid- and late 20th century. J Am Water Resour As. 2012;48(6):1126-1138.

Raff D, Brekke L, Werner K, Wood A, White KD. Short-term water management decisions: user needs for improved climate, weather, and hydrologic information [Internet]. US Army Corps of Engineers Civil Works Technical Series CWTS-2013-1. Washington (DC): US Army Corps of Engineers, Bureau of Reclamation (US), National Oceanic and Atmospheric Administration (US); 2013 Jan [cited 2014 May 05]; 261 p. Available from: <http://www.ccawwg.us/docs/Short-Term Water Management Decisions Final 3 Jan 2013.pdf>

Short MD, Peirson WL, Peters GL, Cox RJ. Managing adaptation of urban water systems in a changing climate. Water Resour Manag. 2012;26(7):1953-1981.

Stockton SL, White KD. (2011) US Army Corps of Engineers' collaborative approach to twenty-first century challenges posed by global change. In: Linkov I, Bridges TS, editors. NATO science for peace and security Series C: environmental security. Climate: global change and local adaptation. Dordrecht (NL): Springer Netherlands; 2011. p. 19-35.

Tebaldi C, Strauss BH, Zervas CF. Modelling sea level rise impacts on storm surges along US coasts. Environ Res Lett [Internet]. 2012 Mar 14 [cited 2014 May 09];7(1): (11 pages). Available from: <http://iopscience.iop.org/1748-9326/7/1/014032/article?fromSearchPage=true>

The University Corporation for Atmospheric Research. Preparing hydro-climate inputs for climate change in water resource planning. MetEd [Internet]; [cited 2014 June 11]. Available from: [https://www.meted.ucar.edu/training\\_module.php?id=959#.U5mwVbGtjt](https://www.meted.ucar.edu/training_module.php?id=959#.U5mwVbGtjt)

US Army Corps of Engineers. Building Strong Collaborative Relationships for a Sustainable Water Resource Future [Internet]. Washington (DC): US Army Corps of Engineers; [cited 2014 May 09]. Available from: <http://www.building-collaboration-for-water.org/>

US Army Corps of Engineers. Engineering and Construction Bulletin. Application of flood risk reduction standard for sandy rebuilding projects [Internet]. December 17, 2013 [cited 2014 June 11]; 2013-33 1-5. Available from: [http://www.wbdg.org/ccb/ARMYCOE/COEECB/ecb\\_2013\\_33.pdf](http://www.wbdg.org/ccb/ARMYCOE/COEECB/ecb_2013_33.pdf)

US Army Corps of Engineers. Engineering and Construction Bulletin. Guidance for incorporating climate change impacts to inland hydrology in civil work studies, design and projects [Internet]. May 2, 2014 [cited 2014 June 11]; 2014-10 1-17. Available from: [http://www.wbdg.org/ccb/ARMYCOE/COEECB/ecb\\_2014\\_10.pdf](http://www.wbdg.org/ccb/ARMYCOE/COEECB/ecb_2014_10.pdf)

US Army Corps of Engineers. Engineering Circular 1165-2-212. Sea-level change considerations for civil works programs [Internet]. October 1, 2011 [cited 2014 June 11]. Available from: [http://www.corpsclimate.us/docs/EC\\_1165-2-212%20-Final\\_10\\_Nov\\_2011.pdf](http://www.corpsclimate.us/docs/EC_1165-2-212%20-Final_10_Nov_2011.pdf)

US Army Corps of Engineers. Engineering Circular 1100-2-8162. Incorporating sea level change in civil works program [Internet]. December 31, 2013 [cited 2014 June 11]. Available from: [http://www.publications.usace.army.mil/Portals/76/Publications/EngineerRegulations/ER\\_1100-2-8162.pdf](http://www.publications.usace.army.mil/Portals/76/Publications/EngineerRegulations/ER_1100-2-8162.pdf)

US Army Corps of Engineers. Federal Support Toolbox [Internet]. Washington (DC): US Army Corps of Engineers; [cited 2014 May 09]. Available from: <http://watertoolbox.us/intro/?p=689:1>

US Army Corps of Engineers. National report: responding to national water resources challenges [Internet]. Washington (DC): US Army Corps of Engineers; 2010 Sep 17 [cited 2014 May 09]; 104 p. Available from: [http://www.building-collaboration-for-water.org/Documents/nationalreport\\_final.pdf](http://www.building-collaboration-for-water.org/Documents/nationalreport_final.pdf)

US Army Corps of Engineers. Response to Climate Change [Internet]. Washington (DC): US Army Corps of Engineers.

Adaptation Policy and Plan; revised 2014 Mar 6 [cited 2014 May 09]. Available from: <https://corpsclimate.us/adaptationpolicy.cfm>

US Army Corps of Engineers. Response to Climate Change [Internet]. Washington (DC): US Army Corps of Engineers. Application of flood risk reduction standard for sandy rebuilding projects; revised 2014 April 9 [cited 2014 June 11]. Available from: <http://www.corpsclimate.us/ccafrrsSandy.cfm>

US Army Corps of Engineers. Response to Climate Change [Internet]. Washington (DC): US Army Corps of Engineers. Coastal risk reduction and resilience: using a full array of measures; revised 2013 September 16 [cited 2014 June 11]. Available from: <http://www.corpsclimate.us/ccacrrr.cfm>

US Army Corps of Engineers. Response to Climate Change [Internet]. Washington (DC): US Army Corps of Engineers. Sea-level change curve calculator; revised 2014 May 29 [cited 2014 June 11]. Available from: <http://www.corpsclimate.us/ccaceslcurves.cfm>

US Army Corps of Engineers. Sea-level change considerations for civil works program. [Internet]. Washington (DC): US Army Corps of Engineers; 2013 Oct 1 [cited 2014 May 09]; 33 p. Available from: [http://www.publications.usace.army.mil/Portals/76/Publications/EngineerCirculars/EC\\_1165-2-212.pdf](http://www.publications.usace.army.mil/Portals/76/Publications/EngineerCirculars/EC_1165-2-212.pdf)

US Army Corps of Engineers. Standards and procedures for referencing project elevation grades to nationwide vertical datums [Internet]. Washington (DC): US Army Corps of Engineers; 2010 Dec 31 [cited 2014 May 09]; 422 p. Available from: [http://www.publications.usace.army.mil/Portals/76/Publications/EngineerManuals/EM\\_1110-2-6056.pdf](http://www.publications.usace.army.mil/Portals/76/Publications/EngineerManuals/EM_1110-2-6056.pdf)

US Army Corps of Engineers. Sustainable solutions to America's water resources needs: civil works strategic plan 2011-2015 [Internet]. Washington (DC): US Army Corps of Engineers; 2011 Sep [cited 2014 May 09]; 28 p. Available from: [http://planning.usace.army.mil/toolbox/library/Misc/Sustainable\\_Solutions-2011-15.pdf](http://planning.usace.army.mil/toolbox/library/Misc/Sustainable_Solutions-2011-15.pdf)

US Army Corps of Engineers. US Army Corps of Engineers Institute for Water Resources [Internet]. Washington (DC): US Army Corps of Engineers. USACE IWR Advances Consistent Methodological Approach for Considering Social Vulnerability and Other Social Effects; 2013 May 03 [cited 2014 May 09]. Available from: <http://www.iwr.usace.army.mil/Media/NewsStories/tabid/11418/Article/13535/usaceiwr-advances-consistentmethodological-approach-forconsidering-social-vu.aspx>

US Army Engineer Institute for Water Resources. Water resources sector technical input-interim report in support of the global change research program 2014 national climate assessment [Internet]. Alexandria (VA): US Army Engineer Institute for Water Resources; revised November 2013 [cited 2014 June 11]. Available from: [http://www.iwr.usace.army.mil/Portals/70/docs/iwrreports/2013-R-10\\_WaterResources\\_Sector\\_TIR.pdf](http://www.iwr.usace.army.mil/Portals/70/docs/iwrreports/2013-R-10_WaterResources_Sector_TIR.pdf)

US Fish and Wildlife Service, National Oceanic and Atmospheric Administration (US), Association of Fish and Wildlife. National Fish Wildlife & Plants Climate Adaptation Strategy [Internet]. Washington (DC): US Fish and Wildlife Service, National Oceanic and Atmospheric Administration (US), Association of Fish and Wildlife; [cited 2014 May 09]. Available from: <http://www.wildlifeadaptationstrategy.gov/>

US Global Change Research Program. Climate change: federal efforts under way to assess water infrastructure vulnerabilities and address adaptation challenges [Internet]. Washington (DC): US Global Change Research Program; November 14, 2013 [cited 2014 June 11]. Available from: <http://www.gao.gov/products/GAO-14-23>

US Global Change Research Program. Resources for evaluating and monitoring climate change adaptation actions in coastal regions: an annotated bibliography [Internet]. Adaptation Science Interagency Working Group; November 2013 [cited 2014 June 11]. Available from: <http://www.globalchange.gov/browse/reports/resources-evaluating-and-monitoring-climate-change-adaptation-actions-coastal-regions>

US Global Change Research Program. Sea level rise tool for sandy recovery [Internet]. Washington (DC): University Corporation for Atmospheric Research; [cited 2014 June 11]. Available from: <http://www.globalchange.gov/browse/sea-level-rise-tool-sandy-recovery>

Villarini G, Scoccimarro E, Gualdi S. Projections of heavy rainfall over the central United States based on CMIP5 models. *Atmos Sci Lett*. 2013;14(3):200-205.

Vogel RM, Rosner A, Kirshen PH. Brief communication: likelihood of societal preparedness for global change: trend detection. *Nat Hazards Earth Syst Sci* [Internet]. 2013 Jul 11 [cited 2014 May 09];13(7):1773-1778. Available from: <http://www.nat-hazards-earth-syst-sci.net/13/1773/2013/nhess-13-1773-2013.pdf>

Wilby RL, Keenan R. Adapting to flood risk under climate change. *Prog Phys Geog*. 2012;36(3):348-378.

# APPENDICES

## Appendix A: Guiding Principles for Adaptation

### PROGRESS REPORT OF THE INTERAGENCY CLIMATE CHANGE ADAPTATION TASK FORCE - 2010

#### *Guiding Principles for Adaptation*

- **Adopt Integrated Approaches**—Adaptation should be incorporated into core policies, planning, practices, and programs whenever possible.
- **Prioritize the Most Vulnerable**—Adaptation plans should prioritize helping people, places and infrastructure that are most vulnerable to climate impacts and be designed and implemented with meaningful involvement from all parts of society.
- **Use Best-Available Science**—Adaptation should be grounded in the best-available scientific understanding of climate change risks, impacts, and vulnerabilities.
- **Build Strong Partnerships**—Adaptation requires coordination across multiple sectors and scales and should build on the existing efforts and knowledge of a wide range of public and private stakeholders.
- **Apply Risk-Management Methods and Tools**—Adaptation planning should incorporate risk-management methods and tools to help identify, assess, and prioritize options to reduce vulnerability to potential environmental, social, and economic implications of climate change.
- **Apply Ecosystem-based Approaches**—Adaptation should, where relevant, take into account strategies to increase ecosystem resilience and protect critical ecosystem services on which humans depend to reduce vulnerability of human and natural systems to climate change.
- **Maximize Mutual Benefits**—Adaptation should, where possible, use strategies that complement or directly support other related climate or environmental initiatives, such as efforts to improve disaster preparedness, promote sustainable resource management, and reduce greenhouse gas emissions including the development of cost-effective technologies.
- **Continuously Evaluate Performance**—Adaptation plans should include measurable goals and performance metrics to continuously assess whether adaptive actions are achieving desired outcomes.

From <http://www.whitehouse.gov/sites/default/files/microsites/ceq/Interagency-Climate-Change-Adaptation-Progress-Report.pdf>

## Appendix B: Climate Change Impacts to Missions and Operations from USACE 2012 Adaptation Plan

On March 31, 2012, the Assistant Secretary of the Army for Civil Works, Jo-Ellen Darcy, submitted letters to CEQ and to OMB stating that a high-level vulnerability analysis to the impacts of climate change had been submitted as requested by them in their *Implementing Instructions for Federal Agency Climate Change Adaptation* issued on March 4, 2011. The high-level analyses were specifically NOT intended to be detailed vulnerability assessments of specific programs, projects, or geographic regions. Rather, they were to serve as a tool for agencies that would provide initial awareness of potential climate change impacts to agency operations, policies and programs, to guide agency priorities.

This Appendix to the USACE 2012 *Adaptation Plan and Report* contains excerpts of the high-level vulnerability analysis at a level of detail and understanding that also meets the requirements of the February 29, 2012 statement on *Preparing Federal Agency Climate Change Adaptation Plans In Accordance with Executive Order 13514*.

Potential water resources management sector impacts identified and discussed in USGS Circular 1331 include changing water availability, variability, demand, and quality; wild-land fires; ecosystem or species transitions or alterations; coastal and estuarine conditions; and energy production and demand. NRC (2010) provided a comprehensive list of climate changes and their associated impacts to ecosystems, based on a wide variety of sources.

For the purpose of the high-level vulnerability analysis, we have outlined potential climate change impacts associated with the drivers discussed above that could impact the selected USACE business areas of Navigation, Flood and Coastal Storm Damage Reduction, Environment, Hydropower, Regulatory, Recreation, Emergency Management, and Water Supply. Table B-1 presents a high-level analysis of impacts, and potential vulnerabilities or opportunities. Table B-2 contains some of the more detailed priority questions facing USACE as we began to manage climate change impacts, organized by business line.

Table B-1.

Projected Climate Change	Potential Impacts	Potential USACE Vulnerabilities/Opportunities
Increasing air temperatures	Increases to average temperature, which will vary regionally and over time; increasing frequency and intensity of extreme heat; increasing length of frost-free season; changes in form of precipitation (snow vs. rain); reduced ice volume and extent on lakes, rivers, oceans, and in glaciers; increased permafrost temperatures and permafrost thawing; changes in water and energy demand; altered habitat suitability; increasing water temperature and associated lake stratification and water quality; changes in invasive species or pest distribution; warmer sea surface temperatures and potentially altered circulation patterns; changed evapotranspiration impacting reservoirs and soil moisture; increased risk of wild fires; alterations in material properties	Increases in worker safety limitations due to extreme heat and intensified air pollution; increased heat-related illnesses; increased risk of wildfire; potential increases in the length of the ice-free shipping season; potential increases in shoreline erosion where shorefast ice no longer exists; altered environmental windows; greater uncertainty of water supply and demand affecting navigation, ecosystem restoration, hydropower, recreation, and water supply; potential changes that affect the delineation of the waters of the US; wetland and other impacts to the regulatory mission; potential increases in energy costs for cooling facilities and potential offsets for heating; potential decreases in the reliability of energy; potential for coastal extreme high water events associated with altered ocean circulation; potential changes in vertical construction equipment, material, and operating responses to increased temperature; threatened and endangered species may be adversely affected or benefit.
Changing precipitation	Changes in seasonal precipitation that vary regionally and seasonally :in general, the northern US is projected to see more winter and spring precipitation and the South is projected to see less precipitation in the spring, and increased precipitation is projected for Alaska in all seasons; increase in the frequency and intensity of heavy and very heavy precipitation events, including in the Southwest, where overall precipitation will be decreasing ( =greater potential for flash floods); increasing frequency, duration, and extent of drought; summer droughts are expected to intensify in most regions of the U.S., especially in the Southwest, Southeast, and Hawaii in response to both rising temperatures and changes in precipitation; changes in snow volume and onset of snowmelt; more variable stream flow and lake levels; altered habitat suitability; changes in invasive species or pest distribution; change in magnitude and frequency of flooding and low flows; altered sediment regimes, streambank erosion, aggradation, and degradation; changes in stormwater magnitude and frequency and levels of pollutants in runoff; altered groundwater recharge and consumptive uses;	Increasing uncertainty in projected precipitation and/or nonstationary hydrology could alter design standards and criteria; more variable reservoir inflow, lake levels, and channel depths could impact performance of flood risk, navigation, ecosystem restoration, hydropower, recreation, and water supply missions; more intense flooding over most of the US, but especially in the Midwest and Northeast requires increased need for emergency preparedness, response and recovery; changes in the delineation of the waters of the US; wetland and shoreline impacts within the scope of the regulatory mission; increasing need for drought preparedness; potential mismatch of water supply and demand could impact existing and planned water allocation and reallocation; ; increasing very heavy precipitation may alter reservoir sediment conditions and changes in dredging requirements for rivers and harbors; increasing potential for wildfire with increased drought; changes in soil moisture could alter infiltration and impact rainfall-runoff relationships; more intense precipitation and runoff generally increase sediment, nitrogen, and pollutant loads, shifts in ecosystem structure and function may adversely impact or benefit threatened and endangered species.

Projected Climate Change	Potential Impacts	Potential USACE Vulnerabilities/Opportunities
Increases in extreme weather	Increasing variability, altered seasonality, and changing intensity or frequency of heat waves, floods and droughts, depending on location; warming sea surface temperatures are projected to result in increasing tropical storm intensity for the largest storms.	Increases in extreme weather and storms will require increased emergency preparedness, response, and recovery; increasing uncertainty in the magnitude and frequency of extreme floods could impact life safety and alter design standards and criteria; more variable reservoir inflow and lake levels could impact performance of flood risk, navigation, ecosystem restoration, hydropower, recreation, and water supply missions; impacts to wetlands shorelines that impact the regulatory missions; more intense and/or frequent heat waves will impact worker safety, potentially limiting construction and operations; increased floods, droughts, and storms impact sedimentation and shoaling, altering dredging requirements; more intense floods and droughts will impact navigation reliability; increased flooding will impact transportation, electrical power, medical, and communications infrastructure.
Sea level change and associated tides, waves, and surges	In Alaska and the Pacific Northwest, locations experiencing glacial rebound may be impacted by falling local relative sea levels, increasing shoreline erosion and the need for dredging. Elsewhere, rising local relative sea level will cause more frequent inundation of low-lying land; increased shoreline erosion and changes to barrier islands and inlets; increased storm waves, surges, tides; loss of or changes to coastal wetlands; changes in estuarine structure and processes; increased saline intrusion into coastal aquifers; altered sedimentation and shoaling in channels and harbors; changes in ecosystem structure and species distributions, including invasive species and pest; altered frequency and extent of harmful algal blooms and coastal hypoxia events;	Increased need for emergency preparedness, response, and recovery for more frequent inundation; increasing uncertainty in the magnitude and frequency of storm tides and surges could alter design standards and criteria; higher average and extreme water levels could impact performance of navigation, coastal risk reduction, ecosystem restoration, and missions; changes in sedimentation and shoaling could impact dredging; decreases in harbor and port performance reliability; changes in delineation of the waters of the US; impacts to wetlands that affect the scope of the regulatory mission.

In keeping with the questions-based approach of the flexible framework for climate change adaptation (CEQ 2010, CEQ 2011), this high-level vulnerability analysis also poses priority questions to guide adaptation implementation planning. Specific questions posed by CEQ (2010) to agencies beginning adaptation planning — and USACE responses to them — include the following:

- What aspects of the climate are changing, at what rates, and over what spatial scale (i.e., at the global, national, regional, and local level)? As a water resources agency, USACE recognizes that changes in temperature and precipitation, the fundamental drivers of the hydrologic cycle, are changing at different – and variable – rates, at all scales, from local to global. These factors are also equally important to our military missions support.
- What uncertainties are associated with the projected impacts of climate change? The primary uncertainties affecting USACE are nonstationarity (due to climate and other global changes) and increasing climate variability.
- How do these compare and relate to other stresses and their uncertainties? Other global changes, especially land use and land cover changes, may outweigh climate change impacts in the near- and mid-term. However, because our water resources infrastructure (both built

and natural) is long-lived, climate and other global changes should be incorporated in all phases of the project life-cycle. The uncertainties associated with other stressors are equal to or less than climate uncertainties, depending on the decision scale.

- How can we characterize and use this uncertainty in our adaptation efforts? USACE is currently exploring nonstationarity issues with other water resources agencies. Uncertainties arising from the selection of analytical processes and methods for use of climate change information in decision-making are also under study by water resources agencies. USACE is also conducting *pilot* tests to identify uncertainties, whether in climate projections or in systems responses.






Table B-3 presents additional questions, directed at the functional areas important in the USACE, which integrate across the business lines.

Table B-2. Climate Change Impacts to Selected Strategic Missions and Goals (after NRC 2010).

Climate Change	Impact	Impacts: Positive (+), Negative (-), or Both	Primary Mission/Goal Impacted*
Increasing average air temperature	Change in form of precipitation (snow vs. rain)	+ -	
	Changes in water temperatures → water quality, lake stratification	-	
	Effects on crops and growing season → changing water demand	+ -	
	Changes in ecosystem structure and function	-	
	Changes in invasive species or pest distribution	+ -	
	Changes in river ice regimes	+ -	
	Changes to glacial processes	-	
	Changes to ocean ice regimes	+ -	
	Changes to permafrost	-	
	Changes in energy demand	-	
Increasing average air temperature	Altered ocean circulation → changing tide & surge regimes	-	
	Increased extreme events → heat/cold waves, ice/dust storms, blizzards	-	
	Changing persistence of large-scale atmospheric features	+ -	
	Changes in evapotranspiration	-	
Changing precipitation: increasing variability, altered seasonality, and changing intensity or frequency of extremes (flood and drought)	Changing or more variable municipal & industrial water supplies	+ -	
	More variable stream flow and lake levels	+ -	
	Changing water conditions for ecosystems	+ -	
	Changing frequency of coastal and riverine flooding	+ -	
	Changes in stormwater runoff	-	
	Changes in drought frequency and intensity	-	
	Changing sediment regimes	+ -	
	Changing levels of pollutants in runoff	+ -	
Sea-level and coastal storm changes and associated tides, waves, and surges	Changes in snowmelt onset and volume	+ -	
	Increased shoreline erosion and changes to barrier islands & inlets	-	
	Loss of or changes to coastal wetlands	+ -	
	Increased storm waves, surges, tides	-	
	Changes in estuarine structure and processes	+ -	
	Altered saline intrusion into coastal aquifers	-	
	Inundation of low-lying land	+ -	
	Increased depth in harbors and channels	+ -	
	Altered coastal sedimentation	+ -	
	Changes in wind regimes	+ -	
	Changes in ecosystem structure and species distributions, including invasive species and pests	+ -	
	Altered frequency & extent of harmful algal blooms & coastal hypoxia	-	

\* Note: there may be secondary and/or tertiary impacts. For example, effects on crops and growing season are shown as potentially leading to changing water demand, but they may also affect our navigation mission if exports change and if supplies to growing areas change. Navigation, Flood and Coastal Storm Damage Reduction, Ecosystem Restoration, Hydropower, Regulatory, Recreation, Emergency Management, Water Supply, Military Missions

Table B-3. Priority Questions Driving USACE Approach to Manage Climate Change.

Priority Questions Driving USACE Approach	Business Line Impacted*	How These Questions Relate to Business Areas
How do we respond to increasing variability of precipitation with climate change?		<p>Increasing variability impacts our capacity to:</p> <ul style="list-style-type: none"> <li>Provide navigation services</li> <li>Manage reservoirs as authorized to provide flood risk reduction, and prepare, respond and recover from floods and coastal storms</li> <li>Effectively plan, design, and manage ecosystem restoration projects</li> <li>Provide reliable hydropower</li> <li>Manage reservoirs for recreation and authorized water supply</li> <li>Provide military mission support at home and abroad</li> </ul> <p>These impacts may be positive or negative, depending on local conditions. For example, a summer season with greater than normal precipitation (but no increase in flood flows) could enhance navigation, hydropower, recreation, and water supply. On the other hand, a winter season with less snow or rain, could improve spring flood risks but decrease summer water supply availability. The competing objectives of flood risk management and water supply could become more difficult to manage. Both floods and droughts can adversely impact stability of nations, especially those already facing other challenges.</p>
How to account for nonstationarity in hydrologic analyses?		Nonstationarity undermines a fundamental assumptions of historic hydrologic and coastal design. Addressing nonstationarity requires new methods, processes, and technologies supporting updated planning, design, and operations of our projects and programs supporting navigation, flood and coastal storm risk reduction, environment, hydropower, water supply, and military missions.
How to perform flood-related and other hydrologic analyses?		<p>Climate change, and variability, and our scientific knowledge of the uncertain future have revealed:</p> <ul style="list-style-type: none"> <li>The need to consider multiple plausible futures</li> <li>That there are many approaches to obtain climate information – which approaches are suitable for which decision?</li> <li>Gaps in knowledge and lack of established methods of performing hydrologic analyses and predicting floods are required to adequately plan, design, and operate our projects and programs supporting navigation, flood and coastal storm risk reduction, environment, hydropower, regulatory, recreation, emergency management, water supply, and military missions.</li> </ul>
How to address the potential for increased drought?		Use of novel and innovative techniques to monitor, plan for, and forecast drought are required to adequately plan, design, and operate our projects and programs supporting navigation, flood and coastal storm risk reduction, environment, hydropower, recreation, water supply, and military missions.
How do we account for sea-level change and changes in waves, tides, surges, and storms?		Changes in sea level, tides, surges, and coastal storms must be accounted for to adequately plan, design, and operate our projects and programs supporting navigation, flood and coastal storm risk reduction, environment, regulatory, emergency management, water supply, and military missions.

 Navigation, 
  Flood and Coastal Storm Damage Reduction, 
  Ecosystem Restoration, 
  Hydropower, 
  Regulatory, 
  Recreation, 
  Emergency Management, 
  Water Supply, 
  Military Missions

Table B-4. Focus Questions for Climate Change and Variability by USACE Functional Areas

Functional Area	Focal Point	Impacts to Consider
Planning/ Policy	Planning transformation means more focused studies performed more quickly	<ul style="list-style-type: none"> <li>How will we include climate change in a way that does not add time and cost to studies already struggling to meet new requirements?</li> <li>How do we improve our understanding of the future without-project conditions?</li> <li>What are the opportunities we can identify in planning?</li> <li>How do we consider a broad enough range of future conditions to support project formulation that supports the project life-cycle and at the same time provide specific information for final decision making?</li> </ul>
Programs/ Project Management	Budget transformation: do fewer things better while funding and prioritizing actions in the Nation's interest	<ul style="list-style-type: none"> <li>How will considering and mainstreaming climate variability and change impact ongoing budget and schedules?</li> <li>How and when will climate change affect budget priorities?</li> <li>How can we plan for the future actions in the Nation's interest (what are they, and when do we need to be ready for them)?</li> <li>What does this mean to recapitalization?</li> <li>Are there opportunities we can capitalize on?</li> </ul>
E&C	Robust engineering, design, water management that consider future conditions, including impacts to cost and schedule during construction	<ul style="list-style-type: none"> <li>What do we know now about climate variability and change that should be included in dam safety and levee safety guidance underway?</li> <li>Where and how are our water control operations sensitive to climate change?</li> <li>Do we know enough to develop new design guidance for hydrology?</li> <li>When, where, and how do we expect climate variability and change to impact project designs?</li> <li>Decreased cold periods may enhance construction scheduling, while increased hot periods may result in delays</li> <li>How can we identify and enhance opportunities?</li> <li>How do we integrate adaptation and mitigation in a way that recognizes the primacy of our CW missions and operations?</li> </ul>
O&M	Sustainable O&M to meet the mission, jointly protecting aquatic resources and reasonable development under future conditions	<ul style="list-style-type: none"> <li>How can we consider and mainstream climate variability and change to enhance our asset management program?</li> <li>How will climate change impact our recreation and natural resources management operations?</li> <li>How will climate change impact the Regulatory program?</li> <li>What types of impacts or benefits can be expected in the environmental stewardship program?</li> <li>How will climate change impact hydropower?</li> <li>Can we expect increased (or decreased) maintenance costs because of changing climate?</li> <li>Are there other opportunities associated with climate variability and change?</li> </ul>
Emergency Management	Continued emphasis on flood and drought risk management and the solutions we shape	<ul style="list-style-type: none"> <li>Where are we most vulnerable to intense rainfall or sudden snowmelt?</li> <li>Are there areas where changes in snow will decrease the need for spring emergency management?</li> <li>How do climate variability and change impact preparedness?</li> <li>Are there opportunities that can be exploited?</li> <li>How can we include climate change in a way that benefits our nonstructural designs and standards?</li> <li>How will climate change impact response and recovery, particularly in coastal areas already subject to isolation due to storm events?</li> <li>How do we work with other agencies to understand and communicate climate impacts to residual risk?</li> </ul>
Military Missions	Continued provision of military support mission	<ul style="list-style-type: none"> <li>How can we consider and mainstream climate variability and change to enhance our asset management program?</li> <li>How will climate change impact our Military Missions support operations?</li> <li>How will climate change impact our installation support, training, natural resources management operations?</li> <li>Where are we most vulnerable to climate-related changes such as intense rainfall, longer more severe drought, thawing permafrost, sea level change, and changes in ecosystems, including invasives and alterations in habitat supporting threatened and endangered species?</li> <li>How will changing intensity of heat waves impact health and safety during all phases of Military Missions?</li> <li>How do we integrate adaptation and mitigation in a way that recognizes the primacy of our Military Missions and operations?</li> </ul>

## Appendix C. Cross-Cutting Strategies

### The National Action Plan to Manage Freshwater Resources in a Changing Climate

The federal ICCATF released the *National Action Plan Priorities for Managing Freshwater Resources* in a Changing Climate (NAP). The NAP makes six major recommendations, each with supporting actions led by different agencies (Table C-1). USACE is the lead agency to implement the three supporting actions for Recommendation 5, *Integrated Water Resources Management*. The team is using the definition of IWRM from the report *Building Strong Collaborative Relationships for a Sustainable Water Resources Future National Report: Responding to National Water Resources Challenges* as shown in the inset box.

**Action 17** addresses working with States and interstate bodies (e.g., river basin commissions) to incorporate IWRM into their planning and programs with attention to climate-change adaptation issues. The goal is to develop practices supporting an IWRM framework for climate change adaptation.

- USACE is funding several climate change adaptation pilot studies that address certain aspects of IWRM. The goal of one pilot study was to collaboratively develop a climate change adaptation strategy to improve the overall quality of the West Maui Watershed, from the summit of Pu'u Kukui to the outer coral reef. Partners in the plan include USACE-Honolulu district, the State of Hawaii Department of Land and Natural Resources (DLNR) and the Department of Health (DOH) with support from NOAA and EPA. Another pilot study involves regional collaboration with the Ohio River Basin (ORB) Alliance. The alliance includes representatives from federal agencies, States, non-governmental organizations (NGOs) and universities. The aim of this pilot study is to collaboratively develop mitigation and adaptation strategies with the ORB Alliance to counteract the anticipated water resources, ecological and infrastructure impacts caused by climate change. One intended product is the formation of a permanent climate change working group within the ORB Alliance.

USACE has also agreed to do an IWRM pilot study with the Delaware River Basin Commission (DRBC). Climate change adaptation would be one component of this study. This pilot study is in the scoping phase. USACE is also discussing a possible IWRM pilot study with the Interstate Commission on the Potomac River Basin (ICPRB) that would include climate change adaptation.

**Action 19** involves working with states to identify their flood risk and drought management “best practices” to prepare for hydrologic extremes so these can be shared among the states and federal agencies.

- The first product was a review of 50 FEMA State Hazard Mitigation Plans followed by a report that describes the findings of the review with respect to a series of themes related to Action 19. The report will be published by the USACE IWR and should be available online in early 2014.
- The second product was a survey of state flood officials to obtain their perspectives on federal and state agency coordination and their views on innovative policies. The report has been completed and will be published as a joint USACE-FEMA document following approval from both agency HQs.

**Action 20** is to “develop benchmarks for incorporating adaptive management into water project designs, operational procedures, and planning strategies.” An interagency technical team including USACE, DOI, USGS, USDA, NRCS, US Forest Service (USFS), EPA and NOAA is working on this action.

- Two reports have been completed. Both reports are being published by IWR and are available online. The first report, *Federal Agency Inventory of Adaptive Management Practices and Policies*, contains an inventory of federal agencies’ adaptive management practices and policies that support adaptive management strategies in the federal government.
- The second report, *Recommendations for Federal Agency Implementation of Adaptive Management for Climate Change Adaptation*, presents key benchmarks to incorporate adaptive management into water resource project planning and operations.

**Action 21** is to “Establish a core training program on climate change science for local, Tribal, and State water resources managers” of Recommendation 6 (Support Training and Outreach to Build Response Capability). USACE is the co-lead on developing training for water managers on climate change supporting Action 21. In this activity, the CCAWWG (see section on External Collaboration) agencies in cooperation with the UCAR COMET Program and the Western Water Assessment have developed a pilot training program that includes both an online course for self-paced training and a set of subsequent residence courses where students apply what they learned through the online training. The on-line training became available in late 2012, and the first two residential courses were conducted in January and March 2013. Two additional training modules are in development.

Table C-1. National Action Plan Recommendations and Actions

Recommendation	Action	Lead Agency	Supporting Agencies
Recommendation 1: Establish a Planning Process	Action #1: Establish a planning process with the capability to identify priority adaptation actions and promote their implementation	DOI	EPA, CEQ
	Action #2: Establish an organizational framework to promote effective management of water resources in a changing climate	EPA	DOI, CEQ
Recommendation 2: Improve Water Resources and Climate Change Information for Decision making	Action #3: Strengthen data for understanding climate change impacts on water resources	DOI	
	Action #4: Create a program to align "hydroclimatic" statistics with today's climate and anticipate future changes	DOI	
	Action #5: Implement surveillance system for tracking waterborne disease/health treats relevant to climate change	CDC	
	Action #6: Provide coastal states/communities with information to identify areas likely to be inundated by sea level rise	NOAA	USACE
	Action #7: Establish interagency effort to expedite implementation of the newly developed wetlands mapping standard	DOI	
	Action #8: Publish guidance on the use of modeled projections for water resources applications	NOAA	
Recommendation 3: Strengthen Assessment of Vulnerability of Water Resources to Climate Change	Action #9: Develop a federal internet portal to provide information on water resources and climate change	NOAA	USACE
	Action #10: Develop a pilot climate change vulnerability index for a major category of water facilities	NOAA	DOI
	Action #11: Continue development of tools and approaches that build capacity for water institutions to conduct vulnerability assessments and implement appropriate responses.	EPA	
	Action #12: Assess vulnerability of watersheds and aquatic system in National Forests and Grasslands	USDA Forest Service	
	Action #13: Promote free and open access to authoritative climate change science and water resources data	NOAA	
	Action #14: Develop nationally consistent metrics for water use efficiency in key sectors	EPA	USDA, DOE
Recommendation 4	Action #15: Consider making water use efficiency an explicit consideration in the revision of Principles and Standards for water resources projects and in the new NEPA guidance on climate change	CEQ	
	Action #16: Enhance coordination among current federal water efficiency programs and create a "toolbox" of key practices	DOI	EPA, DOE, USACE
Recommendation 5: Support Integrated Water Resources Management	Action #17: Work with States and interstate bodies (e.g., river basin commissions) to provide assistance needed to incorporate IWRM into their planning and programs, paying particular attention to climate change adaptation issues.	USACE	
	Action #18: Revise federal water project planning standards to address climate change	CEQ	
	Action #19: Working with States to review flood risk management and drought management planning to identify "best practices" to prepare for hydrologic extremes	USACE	
	Action #20: Develop benchmarks for incorporating adaptive management into water project designs, operational procedures, and planning strategies	USACE	
Recommendation 6: Support Training and Outreach to Build Response Capability	Action #21: Establish a core training program on climate change science for local, Tribal, and State water resources managers	USBR	USACE, NOAA
	Action #22: Focus existing youth outreach programs on climate change and water issues	USDA	
	Action #23: Engage Water Resource Research Institutes at land grant colleges in climate change adaptation research	DOI	
	Action #24: Increase graduate level fellowships in water management and climate change	NOAA	



### The National Fish, Wildlife and Plants Climate Adaptation Strategy

The *National Fish Wildlife and Plant Climate Adaptation Strategy (NFWPCAS)* was released in March 2013 in response to directives from the Congress and Administration to develop the strategy. An intergovernmental Steering Committee of federal, state and tribal agencies, co-chaired by the U.S. Fish and Wildlife Service, National Oceanic and Atmospheric Administration, and the State of New York (on behalf of the states), led development of the strategy. The NFWPCAS was developed by nearly 100 experts from federal, state and tribal agencies and included input from over 55,000 public comments. USACE was represented on the Steering Committee by the Office of the Assistance Secretary of the Army for Civil Works OASA(CW) and USACE staff participated in the development of the NFWPCAS. USACE and OASA(CW) continues to be engaged directly with the NFWPCAS through participation on the Joint Implementation Working Group (JIWG). The JIWG is currently developing an implementation plan for the NFWPCAS.

It is the first nation-wide adaptation strategy developed in partnership by federal, state, and tribal government agencies that provides public and private decision makers with key steps that should be taken over the next 5 to 10 years to safeguard the nation's valuable natural resources and resource-dependent communities in a changing climate. The NFWPCAS provides a roadmap for decision makers and resource managers to use in considering climate change implications to their ongoing wildlife and habitat management activities.

The NFWPCAS identifies seven key goals and associated actions to prepare for and reduce the impacts of climate change on the nation's living natural resources and ecosystem services:

1. **Conserve habitat** to support healthy populations and ecosystem functions in a changing climate.
2. **Manage natural resources for resilience** and adaptation.
3. **Enhance capacity for effective management** in a changing climate.
4. **Support adaptive management** through integrated observation, monitoring and decision-support tools.
5. **Increase knowledge** and information on impacts and responses of fish, wildlife and plants to a changing climate.
6. **Increase awareness and motivate action** to safeguard living resources in a changing climate.
7. **Reduce non-climate stressors** to help fish, wildlife and plants adapt.

These goals are entirely compatible with the revised USACE *Environmental Operating Principles (EOP)*, and are tied to actions of the NAP and National Ocean Policy Implementation Plan (NOPIP). The EOP were developed to ensure Corps missions include integrated, sound environmental practices. These principles provide corporate direction to ensure the workforce recognizes the Corps' role in, and responsibility for, sustainable use, stewardship and restoration of natural resources across the nation. The EOP were introduced in 2002, and revised in 2012 to better reflect the current mission and challenges.

Our climate change adaptation plan and its supporting strategies are aligned with NFWPCAS goals. We include focus areas that address issues of concern in the NFWPCAS

goals, emphasize collaboration and improving our knowledge, manage risk and uncertainty, and are developing policy and guidance to support adaptation, including flexible, adaptive, effective management for changing conditions.

### The National Ocean Policy Implementation Plan

USACE is addressing climate issues identified in the NOIP and taking actions as specified in the NOIP *Appendix*. Our climate programs incorporate collaborative efforts to develop and disseminate methods, best practices, and standards for assessing coastal resilience in a changing climate. Through the use of the Social Vulnerability Index, USACE is able to identify vulnerable populations. Several of our pilot projects have assessed the impacts of sea level change on ecosystem restoration projects. Informed decision-making is at the core of the sea level change adaptation guidance.

USACE is working on the following actions listed in the Appendix in response to the climate issues identified in the NOIP:

**Actions:** “Develop an interagency plan for topographic [primarily Light Detection and Ranging (LiDAR) or equivalent accuracy] and shallow bathymetric mapping to ensure comprehensive and accurate elevation information for coastlines.”

- Interagency Working Group on Ocean and Coastal Mapping, now labeled in law as IOCM-Interagency committee on Ocean and Coastal Mapping (IWG-OCM) is crafting a National Coastal Mapping Strategy (NCMS) for topographic, bathymetric and topo-bathy lidar to ensure comprehensive and accurate elevation information for coastlines. These data are needed for a variety of reasons, including shoreline delineation, inundation modeling, beach renourishment, marine debris identification, nautical chart updates, coastal engineering decision support, coastal vulnerability assessments, and many other uses. This is the first phase of a more comprehensive Coastal Mapping Strategy that will eventually include acoustic bathymetry mapping. The IWG-OCM is building on current coastal mapping coordination activities among NOAA, USGS and USACE to lay the foundation for broader collaboration for:

- coordinated coastal mapping plans and acquisitions
- defining basic quality levels for topo-bathy lidar for broad agreement on data collection standards
- common data management procedures and a whole life cycle approach to data, and

- targeted research and development coordinate R&D on new tools and techniques for data collection and use.

**Action:** “Provide and integrate county-level coastal and ocean job trends data via NOAA’s Digital Coast to enable decision-makers and planners to better assess the economic impacts of climate change and ocean acidification.”

- NOAA’s Economics: National Ocean Watch (ENOW) provides data on six economic sectors that directly depend on the resources of the oceans and Great Lakes: Living Resources (includes commercial fishing), Tourism and Recreation, Marine Transportation, Ship and Boat Building, Marine Construction (includes harbor dredging and beach nourishment), and Offshore Minerals (exploration and production, sand, gravel, oil, gas).

**Action** “Provide coastal inundation and sea-level change decision-support tools to local, state, tribal, and federal managers.”

- USACE has developed a sea level change calculator, which was used in the interagency Sea Level Rise Tool for Sandy Recovery. USACE, NOAA, and FEMA are working on two pilots to test the application of this tool to locations on the gulf coast and the west coast. USACE, NOAA, and the Department of the Interior are working on a Sea Level Rise and Coastal Flooding Impacts Viewer and associated datasets including Digital Elevation Models. Being able to visualize potential impacts from sea level rise and coastal flooding is a powerful teaching and planning tool, and the Sea Level Rise Viewer, map services, and data brings this capability to coastal communities.

## Appendix D: Adaptation Pilot Studies

The pilot projects span a diverse geographic and spatial scale as well as covering different business lines and functional areas. Each of these pilot studies addresses a central question that will help guide us as we develop policy and guidance to mainstream adaptation, including the following:

- How do we allow for shoreline retreat to preserve critical tidal and nearshore ecosystems in a long-term regional planning context?
- What is the relationship between changing climate conditions and reservoir sedimentation, and could this relationship shorten the lifetime of the infrastructure project or impact its flood control pool?
- How do we incorporate climate change considerations into reservoir operating policies that will be robust and adaptive to potential climate changes?
- How will dredging cost requirements at Great Lakes harbors vary in the future as the climate potentially changes precipitation regimes and runoff characteristics?
- Can we develop a conceptual framework for how climate change information might be incorporated into ecosystem restoration projects?
- Is mountain snowpack and subsequent runoff changing due to changes in climate, and is the Missouri River Basin, therefore, more susceptible to droughts and floods?
- How do we facilitate well-designed and inclusive multi-stakeholder collaboration with the local decision makers for the purpose of identifying vulnerability to sea-level change impacts, acceptable levels of risk, and the most acceptable alternatives over the project lifecycle?



### Cochiti Dam and Lake, New Mexico

*Climate Change Associated Sediment Yield Changes on the Rio Grande in New Mexico: Specific Sediment Evaluation for Cochiti Dam and Lake* (pdf, 3.43 MB)



#### Central Question Addressed by Pilot

What is the relationship between changing climate conditions and reservoir sedimentation, and could this relationship shorten the lifetime of the infrastructure project or impact its flood control pool?

#### Vulnerable Business Lines

Flood Risk Reduction, Navigation, Hydropower, Recreation

### Garrison Dam, North Dakota

*Climate Change Associated Sediment Yield Impact Study: Garrison Dam Specific Sediment and Operation Evaluations* (pdf, 1.77 MB)



#### Central Question Addressed by Pilot

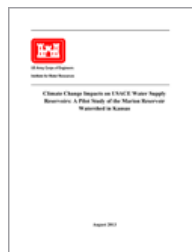
How will climate change affect basin runoff, sedimentation rates, and operations of the Garrison Dam?

#### Vulnerable Business Lines

Flood Risk Management

### Marion Reservoir Watershed, Kansas

*Climate Change Impacts on USACE Water Supply Reservoirs: A Pilot Study of the Marion Reservoir Watershed in Kansas* (pdf, 1.65 MB)



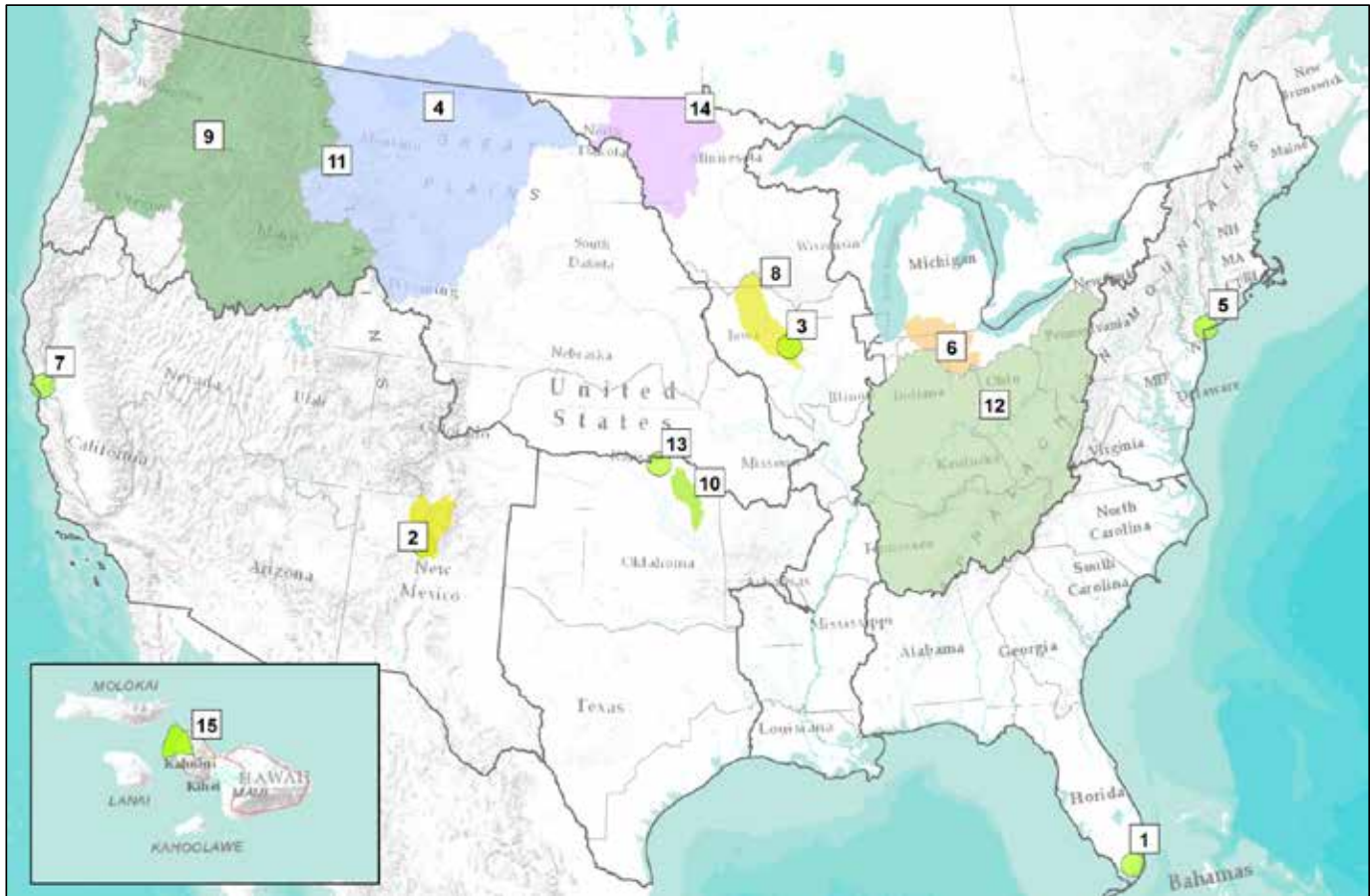
#### Central Question Addressed by Pilot

How can climate modeling be incorporated as a decisionmaking tool with respect to existing and future water supply contracts?

#### Vulnerable Business Lines

Water Supply, Flood Risk Management

## LOCATION MAP FOR THE RESPONSES TO CLIMATE CHANGE ADAPTATION PILOT STUDIES



## KEY

- [1] Application of Sea-Level Change Guidance to **C-111 Spreader Canal**, Florida
- [2] Climate Change Associated Sediment Yield Impacts on the Rio Grande, **Cochiti Dam and Lake**
- [3] Climate Change Impacts on the Operation of **Coralville Lake**, Iowa
- [4] Climate Change Associated Sediment Yield Impacts and Operation Evaluations at **Garrison Dam**, North Dakota
- [5] **East Rockaway Inlet to Rockaway Inlet**, New York, Collaboration Framework Development
- [6] Upland Sediment Production and Delivery in the **Great Lakes Region** under Climate Change
- [7] Risk-Informed Decision-Making for Potential Sea-Level Rise Impacts on the **Hamilton Wetland** Restoration Project, California
- [8] Climate Modeling and Stakeholder Engagement to Support Adaptation in the **Iowa-Cedar Watershed**
- [9] Framework for Building Resiliency into Restoration Planning – **Lower Columbia River Estuary**
- [10] Utilization of Regional Climate Science Programs in Reservoir and Watershed Risk-Based Assessments, **Oologah Lake and Watershed**
- [11] **Missouri River Basin** Mountain Snowpack – Accumulation and Runoff
- [12] Formulating Mitigation/Adaptation Strategies through Regional Collaboration with the **Ohio River Basin** Alliance
- [13] Climate Change Impacts on Water Supply in **Marion Reservoir Watershed**, Kansas
- [14] **Red River of the North** Flooding at Fargo, North Dakota
- [15] Risk-Informed Decision-Making for Integrated Water Resource Management Planning, **West Maui Watershed**

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Figure 12. Pilot Study Locations